NATIONAL DEFENSE INDUSTRIAL ASSOCIATION

STRENGTH THROUGH INDUSTRY & TECHNOLOGY

NON-LETHAL DEFENSE III

Johns Hopkins Applied
Physics Laboratory
Laurel, Maryland

February 25&26, 1998

REVISED AGENDA

NON LETHAL DEFENSE III CONFERENCE

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INTRODUCTION TO NON-LETHAL DEFENSE III PROCEEDINGS

Johns Hopkins
Applied Physics Laboratory

Laurel, Maryland

25 and 26 February, 1998

John B. Alexander, Ph.D.
Organizer and Chairman

Non-Lethal Defense III is designed as a response to the requirements articulated in Non-Lethal Defense II held 6-7 March 1996 in Arlington, Virginia. At that time senior defense and law enforcement officials discussed what they believed to be an urgent need for the research, development, and acquisition of new non-lethal weapons. Since then, the US Department of Defense has formalized the Non-Lethal Weapons Program and created the Joint Non-Lethal Weapons Directorate to administer that program.

In addition to many technical presentations, you will hear from the key people responsible for making this program a reality. They will include the policy people from the Office of the Secretary of Defense, National Security Council, and National Institute of Justice. You will also be exposed to soldiers and law enforcement officials who have been on the ground bringing non-lethal weapons to peace support in Bosnia, Haiti, Somalia and other hot spots as well as to the streets of America.

In the development of this conference we have had many calls from representatives of foreign governments. A few have chosen to present. Others are here to observe. Having served on several NATO studies relating to non-lethal weapons, I know of both the interest and controversy surrounding the introduction of these systems. The reality is that some of you have far more experience than we in use of force during difficult domestic situations. We can learn from that and hope that you will contribute to the sessions.

Most, but not all, of the papers are included in these proceedings. Abstracts of papers that were missing at the publication date are included. Also, we received some abstracts too late to be include in the agenda. However, I considered the information to be significantly important that I included them in this package. Time permitting we will attempt to fit them into a very tight schedule.

It should also be noted that the napers were received in a camera ready condition. Therefore, except in rare electronic submissions, I did not edit the papers for spelling or grammar. Rather. they were photocopied exactly as they arrived.

As with all conferences of this nature, a number of people have worked for several months to pull it all together. We are indebted to the program committee for their contributions. They Include:

- Office of the Secretary of Defense - Mr. Don Henry, Dr. Wes Kitchens
- Joint Non-Lethal Weapons Directorate - Mr. Kevin Stull, Ms. Susan LeVine
- National Institute of Justice - Dr. Ray Downs
- Army Materiel Command - Ms. Hildi Libby
- Office of Naval Research - Col. Paul Roques, USMC
- Oak Ridge National Laboratory - Dr. Clay Easterly
- Sandia National Laboratories - Mr. Steve Scott

The conference administration has been handled by personnel from the National Defense Industrial Associate (NDIA). The participants in our planning sessions include:

- MG Paul Greenberg, US Army (Ret), Vice President, Operations
- Mr. Joe Hylan, Director, Operations
- Capt. Nelson Jackson, US Navy, (Ret)
- Ms. Michele xxxx

NON-LETHAL WEAPONS AND THE WARFIGHTER

Lieutenant General Martin R. Steele
United States Marine Corps

The Joint NLW Concept

"Guiding Principles"

- Leverage High Technology
- Enhance Operations
- Augment Deadly (Lethal) Force
- Provide Rheostatic Capability
- Focus on Tactical Applications
- Expeditionary
- Acceptable
- Reversible Effects

The Joint NLW Concept

"Core Capabilities"

- **Counter-Personnel**
  - Crowd Control
  - Incapacitate Individuals
  - Deny Access
  - Clear Facilities/Structures
- **Counter-Materiel**
  - Area Denial (land, sea and/or air space)
  - Disable/Neutralize Equipment or Facilities

Department of Defense Non-Lethal Weapons Policy

Mr. Charles Swett

Office of the Secretary of Defense

OASD(SO/LIC) Policy Planning

U.S. Policy

"I will...direct the Office of the Secretary of Defense to accelerate efforts to field non-chemical, non-lethal alternatives to Riot Control Agents for use in situations where combatants and noncombatants are intermingled."

President Clinton
June 23, 1994
Letter to the Senate transmitting the Chemical Weapons Convention for ratification

Requirements For Non-Lethal Weapons, I

"We've got to find ways of taking people out without killing them and causing damage -- something tnat can do more than a Riot Control Agent. I'm talking about the whole American peacekeeping mission (needing such harmless but effective agents). We're looking at things that can be used on crowds of people."

General Wayne Downing
CINC USSOCOM

"...Employ a range of capabilities more suitable to actions at the lower end of the full range of military operations which allow achievement of military objectives with minimum casualties and collateral damage."

Admiral W. A. Owens
Vice Chairman, JCS (former)

(DoD) will be called upon increasingly ... to think through the *policies* and programs needed to give us the option of offensive action to deter, *disable*, or *disarm*, or pre-empt would-be WMD users... we should aggressively pursue the means to pre-empt or *disable* such weapons and associated support infrastructure using "non-lethal weapons."

USD (P) (former)

Requirements For Non-Lethal Weapons, II

"...Military Police operations, particularly military operations other than war (OOTW), combined with restrained rules of engagement, lead themselves to scenarios where non-lethal technologies would be preferred..."

U.S. Army Military Police School

"...USACOM requirements for non-lethal systems fall into three general categories:

a. Immediate NLS in support of ongoing operations in the Caribbean

b. NLS to support ongoing counterdrug operations executed by USACOM subordinates and components

c. NLS to support the full spectrum of other ongoing, future, and potential USACOM missions ranging from general war, through Special Operations/Low-Intensity Conflict, to providing DoD support to law enforcement agencies in mitigating/terminating civil unrest/disobedience..."

Capt. R. L. Wright, USN
Director, Program Planning and Assessment
U.S. Atlantic Command

Requirements For Non-Lethal Weapons, III

- J-3: Need certain classes of non-lethal weapons
- EUCOM:
  - Need non-lethal weapons to support operations across spectrum of conflict
  - Especially interested in use against WMD targets
- SOUTHCOM:
  - Holding aircraft on the ground
  - Forcing aircraft to land
  - Neutralization of hostiles intermingled with non-combatants
  - Crowd control

Requirements for Non-Lethal Weapons, IV

"U.S. forces are increasingly being tasked to support peace operations, humanitarian assistance and operations other than war where traditional riot control and security measures are inappropriate. Recent USACOM operations in Haiti and Guantanamo Bay demonstrated the need for non-lethal weapons."

General John Sheehan

CINC USACOM

"Non-lethal technologies afford commanders expanded crisis and contingency response options beyond the use of traditional lethal weapons. These technologies will be even more useful and important in the future."

General J. H. Binford Peay III

CINC USCENTCOM

"We need to provide our soldiers an alternative to deadly force... Non-lethal weapons provide this alternative while retaining the capability to protect our soldiers and non-combatants in complex and potentially volatile situations."

General Dennis Reimer

CoS USA

Requirements for Non-Lethal Weapons, V

"Our experience in Somalia with nonlethal weapons offered ample testimony to the tremendous flexibility they offer to warriors on the field of battle.

Their use better enables us to respond proportionately and with greater flexibility to the wide range of threats we can expect to face today and in the future."

General Charles Krulak

Commandant

United States Marine Corps

Bureaucratic History

- Considerable attention by OSD in 1990-1991
  - Non-lethal Weapons Task Force
  - Recommended aggressive development and fielding
  - USD (P) Wolfowitz suggested to SecDef that non-lethal weapons be pursued
  - USD (A) Yockey disagreed and effort was discontinued
- Current administration
  - Dr. Deutch meeting with Council on Foreign Relations
  - Non-lethal Weapons Steering Committee established
    - Develop acquisition plan
    - "Call for ideas" for non-lethal weapons concepts issued by OUSD (A&T)
  - Request OUSD (P) to develop DoD-level policy for non-lethal weapons
- Controversy over Riot Control Agents in Chemical Weapons Convention
  - President Clinton to direct OSD to pursue non-chemical Riot Control Agents
- Defense Science Board summer study of Military Operations in Built-up Areas
  - Endorsed need for non-lethal weapons

Growing Need for A Non-Lethal Weapons Policy

- Strategic value
  - Expand set of options available to policymakers and commanders for operations short of war
  - Force multiplier in war
  - Reduce costs of conflict across the spectrum
  - Strengthen deterrence by reinforcing flexible response capabilities
  - Leverage U.S. lead in advanced technology
- Widespread interest
  - White house
  - Congress
  - Military
  - Private institutions
  - Media
  - U.S. allies
- Acquisition decisions -- guidance needed on what systems to acquire
- Political sensitivity

Example Non-Lethal Policy Issues

- How prominent a role should non-lethal weapons play in our Defense posture:
  - High profile, to maximize deterrence, or
  - Low key, so as not to encourage development/proliferation of countermeasures?
- What kinds of non-lethal weapons should DoD acquire and what kinds should we not acquire?
- In what circumstances should/can non-lethal weapons be used?
- Do non-lethal weapons using hallucinogens or other psychotropic substances qualify as Toxic Chemicals or Riot Control Agents under the CWC?
- Should anti-personnel lasers be banned?
- How should various new non-lethal weapons concepts be classified?

Definitions from Chemical Weapons Convention

- Toxic Chemical

  Any chemical which through its chemical action on life processes can cause death, temporary incapacitation or permanent harm to humans or animals.

- Riot Control Agent

  Any chemical not listed in a Schedule, which can produce rapidly in humans sensory irritation or disabling physical effects which disappear within a short time following termination of exposure.

Policy Development Approach

- Analysis of national security policy implications of non-lethal weapons (Jaycor)
- Three-phase review process for draft non-lethal weapons policy
  - Informal in-house review by small number of offices in OSD and the Services
  - Widespread review by entire community
    - Get everyone thinking about the issues
    - Ascertain reactions
    - Prepare concerned organizations to receive policy
    - Identify gaps/inaccuracies in draft policy
    - Facilitate formal coordination
  - Formal coordination
    - Approval:DoD Directive 3000.3, "Policy for Non-Lethal Weapons," John P. White, Deputy Secretary of Defense, July 9, 1996

Non-Lethal Weapons Policy

Definition

Non-lethal Weapons are weapons that are explicitly designed and primarily employed so as to incapacitate personnel or materiel, while minimizing fatalities, permanent injury to personnel, and undesired damage to property and the environment.

Unlike conventional lethal weapons which destroy their targets principally through blast, penetration and fragmentation, Non-Lethal Weapons employ means other than catastrophic physical destruction to prevent the target from functioning.

Non-Lethal Weapons have one, or both, of the following characteristics:

- They have relatively reversible effects on personnel or materiel
- They affect objects differently within their area of influence

Non-Lethal Weapons Policy

General Principles

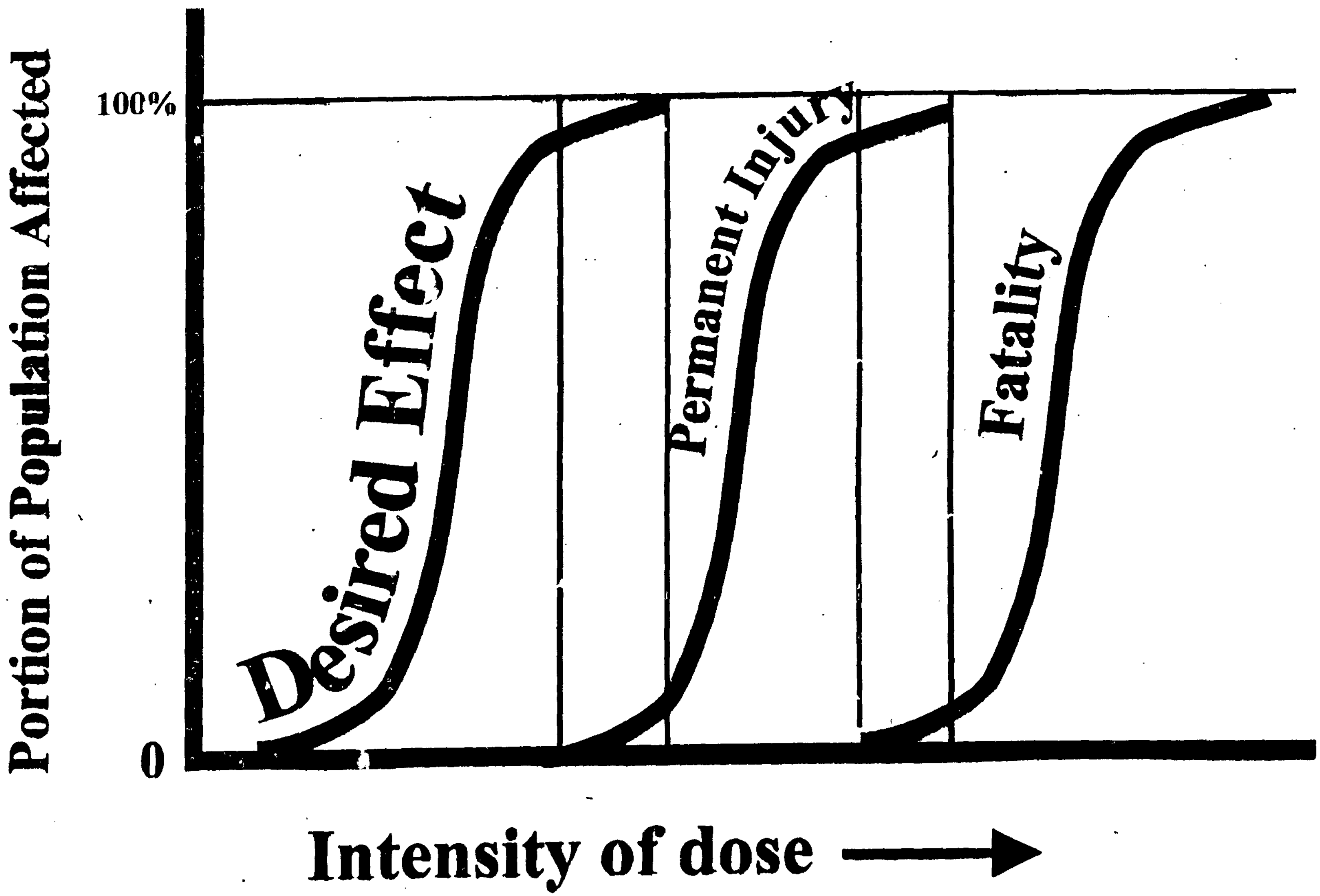
- Non-Lethal Weapons, doctrine, and concepts of operation shall be designed to reinforce deterrence and expand the range of options available to commanders
- Non-Lethal Weapons should enhance the capability of U.S. forces to accomplish the following objectives:
  - Discourage, delay, or prevent hostile actions
  - Limit escalation
  - Take military action in situations where use of lethal force is not the preferred option
  - Better protect our forces
  - Temporarily disable equipment, facilities, and personnel

Draft Non-Lethal Weapons Policy

General Principles (Continued)

Non-Lethal Weapons must achieve an appropriate balance between the competing goals of having a low probability of causing death, permanent injury, and collateral material damage, and a high probability of having the desired anti-personnel or anti-materiel effects.

Anti-Personnel Effects of Non-Lethal Weapons



Non-Lethal Weapons Policy

General Principles (concluded)

- Non-Lethal Weapons will not be required to have a zero probability of producing fatalities or permanent injuries
- Availability of Non-Lethal Weapons will not limit a commander's authority and obligation to use all necessary means and take all appropriate action in self-defense
- No obligation for their employment; U.S. retains the option for immediate use of lethal weapons where appropriate

Potential Criticisms of Non-Lethal Weapons

From the left

- Make war more likely by reducing its destructive consequences
- Violate international treaties
- Damage the enviroment
- Are unethical and inhumane
- Cost too much and/or don't work
- Part of a military-industrial conspiracy to preserve influence in the post-Cold war world

From the right

- Show lack of resolve
- Encourage micromanagement of the military by politicians
- Weaken the effectiveness of U.S. military forces
- Put the lives of U.S. soldiers at risk
- Do not produce the physical effects necessary to punish aggressors

Courting the Law Enforcement Technology Market

by
Sid Heal
Los Angeles Sheriff's Department

[redacted]w "high tech" are we?

- [redacted]urrent Force Options have been [redacted]round since the 1800's
  - [redacted] Colt "Peacemaker" or Beretta 92F?
  - [redacted] Billy club or Expandable Baton?
  - [redacted] Body Armor or Suit of Armor?
- [redacted]inetic Energy and Blunt Trauma
  - [redacted] Pain is OK, Injury is not
- [redacted]Ve ***need*** better tools!

Technology:
Can it Make a Difference?

A View from Hollywood

[redacted]rketing Concerns

- [redacted]aw Enforcement Market is Fragmented
  - [redacted] More than 17,000 agencies
  - [redacted] Most have less than 50 employees
- [redacted]ilitary "Basic Infantryman" concept vs. [redacted]aw Enforcement's Specialists
  - [redacted] Versatility features to the military are "Bell's and Whistles" to Law Enforcement

[redacted] e Questions

- [redacted] nsemble or Components?
- [redacted] echnological Fix or Mechanical Fix?
- [redacted] ff-The-Shelf or "Cutting Edge?"
  - [redacted] Better is the enemy of good enough
- [redacted] dentification or Alert?
  - [redacted] Interpretation is not usually an advantage
- [redacted] arket Pull or Technology Push?
  - [redacted] Solutions looking for Problems

[redacted]e Rules

- [redacted]he Standard is *not* perfection, the [redacted]tandard is the alternative!
- [redacted]alse Positives are Acceptable — False [redacted]egatives are Not
- [redacted]void emotion arousing “Buzz” Words [redacted]nd Acronyms
- [redacted]o not Raise Medical or Biological [redacted]ssues
- [redacted]he Magic Number is 3/4 of a second

[redacted]

pediments

nteroperability with other systems
- Existing Delivery Devices
- Over the Counter Consumables

Hidden and "Soft" Dollars
- Training
- Consumables
- Maintenance

[redacted]ow Stoppers

- [redacted]ocal law enforcement has **no** R&D [redacted]noney
  - Local taxpayers are not patient with people "experimenting" with their money
- [redacted]eturn On Investment (ROI) must be [redacted]within the tenure of elected officials
  - When challenged, provides "the stick to beat them with"

Questions?

Lt. Sid Heal
Los Angeles Sheriff's Dept.
213-980-2202
CSHeal@lasd.org

THE MISSING TOOLS ARE "OFF THE SHELF"

In 1994, U.S. Marines troops were defending unruly migrant crowds at Guantanamo Bay, Cuba. These people were in custody for an extended period of time under intense heat without word of their future destination. The detainees revolted. The fences separating the troops and the Cubans nearly collapsed. Had a full-blown riot erupted, the U.S. forces would have been vastly outnumbered. The majority of the U.S. forces were predominantly young and lacked combat experience. The forces were armed with four-foot riot batons and M-16s with bayonets. As the riot swelled, the gravity of a potential international incident loomed. Although the U.S. troops had plenty of firepower, lethal force was not a viable option. Consequently, the troops were severely handicapped without effective anti-riot weapons or proper non-lethal devices in this nightmare arena. Should the troops have fired or retreated? There was no middle ground.

Fortunately, this situation did not reach the supercritical stage provoking the use of deadly force – the use of which could have caused a serious international incident. Unfortunately, this situation was very real and continues to stymie U.S. forces. Similar situations occur with more and more frequency as attested by incidents in Cuba, Panama, Haiti, Bosnia and the humanitarian relief efforts in Somalia. Moreover, U.S. troops continue to be involved in more peacekeeping and low intensity conflict situations than ever before. These tenuous situations have become the rule and not the exception particularly since the end of the Cold War. Although the potential for full-scale war necessitates the development of precise, lethal and smart weapons, American troops now find themselves in situations where they do not have all the optimum tools that technology can provide -- especially for peacekeeping and humanitarian situations.

Police are not immune from these increasingly dangerous scenarios. A classic example of the need for non-lethal weapons is the story of a homeless man who slept across the street from the White House in Lafayette Park in 1995. National Park Police approached the homeless man. He had a knife and was well within the 21-foot kill zone of the officers. He was shot several times and killed when he did not surrender the weapon. Police were clearly in danger with the lethal knife, but adequate tools to put the man down without loss of life were not in hand.

In today's warfare abroad and on the streets of America, an individual's decision to use or not use deadly force is no longer a tactical decision. Instead, these are now strategic decisions with results that can be broadcast throughout the world in minutes. The future of soldiering presents operational situations where non-lethal weapons and capabilities are needed, but unavailable. The given scope of military operations and particularly peacekeeping missions assumes a "dirty battlefield" in which civilians and non-combatants are mixed with combatants. **American forces and law enforcement must have the capability to react with the right response and not necessarily a lethal response.**

Therefore, innovative weapons are needed to inflict little or no collateral damage to civilian bystanders, including women and children. Although non-lethal weapons imply no permanent damage to individuals, soldiers must still have lethal capability and use of the currently fielded weapons platforms. In addition, the system must have a near instantaneous effect that is accurate, effective and lightweight.

The need to arm America's professional fighting forces and law enforcement with precise, effective, easy to use and trusted lethal and non-lethal weapons is overwhelming considering the increasingly complex missions. The success of peacekeeping missions and the future of law enforcement in an increasingly litigious environment will depend on the ability of these forces to safely control civilians and non-combatants in dirty battlefields and violent American streets in order to succeed in the missions

of tomorrow. The 21st Century warrior and police officer will have access to non-lethal weapons that can easily be used alongside current lethal handguns and rifles. **With this proposed technology, the peacekeeping forces will be properly armed with the option of using either lethal or non-lethal force with current highly effective and "off-the-shelf" products at extremely low cost.**

NON-LETHALITY BACKGROUND

At the Non-Lethal Defense II Conference, the NDIA asked industry to provide non-lethal weapon capability that would minimize excess equipment requirements of the foot soldier. This technology must be lightweight, easily deployable, highly effective, reliably non-lethal, and low in cost.

Having established that the end goal is neutralization of the target's ability to retaliate, there are a limited number of fundamental approaches to achieve this end.

A. **Lethal Force.** Effective lethal force removes the ability of the target to retaliate by permanently interrupting normal life functions. Mechanisms that disable the nervous system or physically disable use of the arms or hands (assumed to be necessary for retaliation) are most effective. Mechanisms that cause lethality by less immediate means such as blood loss are less effective as there is an intervening time period between use of force and expiration during which retaliation could occur. The costs associated with lethal weapons generally include the price of the weapon and the ammunition. However, the societal costs of litigation, international diplomacy risks and medical recovery add magnitudes of costs often not calculated in this area.

B. **Kinetic Force:** Weapons using kinetic force simply knock down the target by imparting sufficient momentum to the body of the target to knock it to the ground or to stun severely. The simplicity and cost effectiveness of kinetic force instruments are significant advantages. However, force metering and placement of impact are significant problems. The fundamental problem with these technologies is that variances in pain thresholds and body mass make for difficult trade-offs between effectiveness and injury. For example, an impact device that can drop a 300-pound individual could easily stop the heart with a direct hit to the chest. Further, sufficient force to take down a large target could cause serious injury or death if delivered at certain impact points such as the head or central sternum.

C. **Physical Restraint:** Weapons based on physical restraint seek to physically prevent aggressive movement by the subject. Examples of physical restraint systems are nets that wrap around the target, or the well-publicized "sticky goo" gun that entangles the target in a web of highly adhesive foam, impeding movement. Physical restraints face several implementation issues. First, for immediate neutralization, several appendages must be simultaneously immobilized to effectively prevent retaliation. Second, over-restraint poses risks of physical injury. For example, a net projected with enough force to ensure the target is bound sufficiently to prevent movement of the arms and hands could also bind around the throat, restricting breathing. Nets are typically bulky, single shot, limited in range, not deployable with current weapon platforms, time-consuming for reloading, and are capable of detaining only a single rioter per deployment. The incapacitation is for a very short period of time and requires apprehension to be fully effective. In Somalia, the U.S. Marines were unable to fully utilize the sticky foams as coating someone entirely in it could have been lethal if it covered the faces of the Somalians. In addition, the costs associated with the cleanup of these chemicals are high and very time-consuming as well.

D. **Physical Impairment:** One could also disable a target by causing an impairment of its physical systems. For example, some chemical sprays can cause sufficient swelling of the membranes around the eyes as to prevent effective sight. This approach shows promise, but current technologies have a delay to efficacy – i.e., the required reactions take time (up to 20 seconds). Further, the target may be able to retaliate without the impaired system. (For example, a blinded target may simply return fire randomly, or may by able to use other senses such as sound or touch to guide a response. Any chemical that relies on pain infliction for its result can be overcome with protective equipment and/or training and mental focus. For greatest efficiency, multiple body systems need to be simultaneously disabled.

E. **Psychological distraction:** The infliction of sufficient pain as to cause the target to focus on self-preservation rather than aggressive behavior. Again, many chemical agents operate on this principle. However, the human body's ability to suppress pain in combat situations gives certain persons, especially those with high tolerance for pain, the ability to function effectively in spite of severe discomfort. In some instances, infliction of pain on the target may incite a more vehement retaliation rather than suppressing one.

F. **Neurological Interference:** Weapons can be used to disable or block the nervous system of the target. If the central command and control system of the human body is disabled, the functioning of all potentially aggressive sub systems is irrelevant. If the target loses the ability to control his muscles, no physical response would be possible. There are two general methods to attack the nervous system: Chemical (tranquilizer darts) and electrical (stun guns or remote stun devices sold under the trade name TASER®).

i) **Chemical Neuro-Inhibition:** Nerve signals are transmitted between nerves within the body using chemical agents that are secreted from one nerve to stimulate another. Chemicals such as those used in anesthetics block the transmission of these chemical signals between nerves – hence causing impairment of neurological function and resulting in loss of consciousness. On the other end of the spectrum, chemicals used in weapons such as nerve gas cause the over excitement of neurochemical junctions. The result is a loss of neurological control as the nervous system "overheats" and gets out of control. The prime drawback in use of neurochemicals in non-lethal weapons is dosage administration. The effect of neurochemicals is dependent on their concentration in the body. Hence, an amount of neurochemical sufficient to tranquilize a large body mass would reach much higher concentrations in a person with small body size with potentially severe implications. Further, there is a necessary latency time during which the chemical must diffuse through the blood stream to the synapses (the chemical junctions between nerve endings) where the effect will occur.

ii) **Electrical Neuro-Inhibition:** Nerve signals are transmitted along a nerve cell, or nerve fiber, using an electrical charge. Hence, much as artificial electronic muscle stimulators are used to stimulate nerves and muscles for therapeutic purposes, electrical signals can be used to interfere with normal nerve signaling within the body. The key advantage over other methods is in dose administration. Neurons use only one amplitude of electrical signal – so the electrical signal used by a nerve cell in a 300-pound man would be indistinguishable from that used by a neuron in an infant. The body does not vary the amplitude of nerve signals, it is the pattern or frequency of the electrical signals which are used to communicate within the body. In effect, the human nervous system is a telegraph system, using patterns of

electrical blips to communicate. It thus becomes possible to "jam" this communication system by injecting electrical blips that disrupt or mask the normal patterns to the point that effective communication within the body is no longer possible.

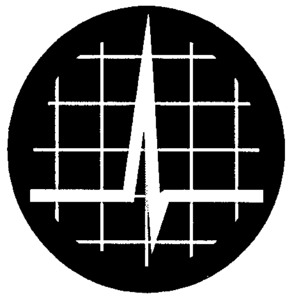
One potential risk would be the inadvertent stimulation of one of the body's life sustaining systems. Fortunately, the cardiac tissues respond to a different wavelength than the conscious nervous system. Hence, it becomes possible to neutralize a target's conscious nervous system without impairing functionality of the cardiac system. If the impairment is administered correctly, breaks can be given which assure respiratory function. Further, because electricity travels at a speed approximating the speed of light, the time to effect is extremely short – the nervous system can be effectively disabled before it can formulate a reaction. Electrical interference offers an extremely fast efficacy for disabling the aggressive potential of a human target in a manner that does not affect vital life support systems.

Each of these approaches to non-lethal weapon technology offers trade-offs of effectiveness versus potential injury during use and can be high in actual cost and associated cost in their use. However, based on the above analysis of these technologies, electrical neuro-inhibition offers the greatest potential for fast, complete neutralization with minimal trauma and at the lowest cost. In fact, it is possible to calibrate this electrical energy for different systems achieving results such as dropping a 1,500-pound buffalo to the ground in less than one second without injury.

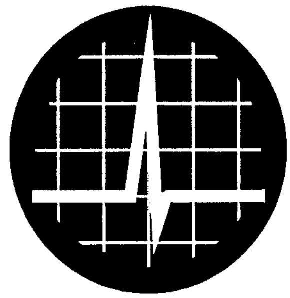
Currently, there are methods that utilize high voltage, low amperage electrical signals against the nervous system for temporary incapacitation. However, as with the other non-lethal options available, these products have some undesirable limitations. With stun guns, for example, the high voltage signals are applied by physically placing the device directly to the skin. Contact with the skin does not cause full incapacitation, but it does inflict uncomfortable to moderate localized pain. Although this can keep someone at bay, it does require hand-to-hand contact, thereby severely limiting the value of these devices for military application.

A more powerful approach uses an off-the-shelf TASER type weapon that provides 15 feet of standoff capability. Formed in 1993, AIR TASER, Inc., implemented electrical neuro-inhibition technology for use in the field in a product called the AIR TASER®. The AIR TASER uses compressed air to disperse two probes connected by wire back to a hand-held power supply. The probes attach to either skin or clothing. Properly calibrated pulses are then transmitted along the wires and into the nervous system of the target, achieving neutralization without physical injury. The resulting jamming of the nervous system's communication prevents coordinated action and requires several minutes for recovery.

The AIR TASER is effective because it overrides the nervous system of the human body. As previously mentioned, the human nervous system communicates by means of simple electrical impulses. Illustrated schematically below, the AIR TASER sends a series of discrete electrical impulses (called Taser-Waves or T-Waves™) quite similar to those used by the human body for communication (for illustrative purposes, these nerve signals are called "brain waves").



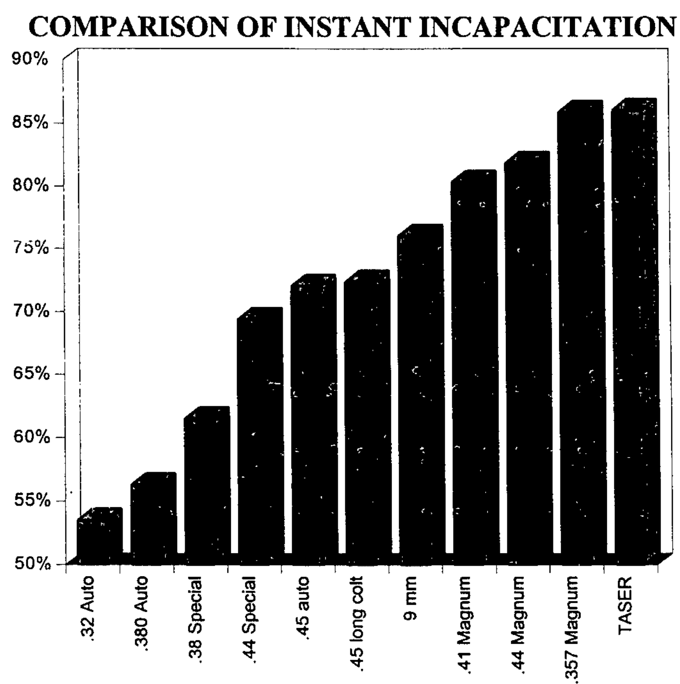
NERVE SIGNAL
or "Brain Wave"



AIR TASER SIGNAL
or "T-Wave"

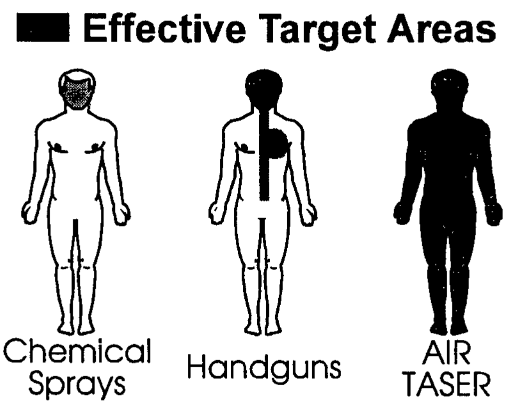
The AIR TASER's T-Wave output overpowers the normal electrical signals within the nerve fibers. Very similar to "radar jamming," the nerve communication blips are washed out in a sea of "white noise" created by the T-Wave electrical impulses. The human target loses control of the neuromuscular system, as coordinated action is severely impaired.

The following graph compares actual field data of the TASER to a variety of handguns based on percentage of targets that are immediately incapacitated.[i] The actual effectiveness in use of the TASER matches or surpasses those for handguns with an 86% instant incapacitation rate.



Notice that this sample is biased **AGAINST** the TASER in that the vast majority of the people who were shot by a TASER (86% in one study) were on phenylcyclohexlpiperidine (PCP). Note that people on PCP frequently break their own bones without notice and are infamous for their ability to absorb bullets without going down.

The reason that the TASER is so highly effective is that the electrical signal penetrates the nervous system regardless of the placement of the probes. The entire human body is covered by a neural net that the AIR TASER uses to knock out its target. The probes do not have to penetrate the flesh or cause bodily harm to be effective because the AIR TASER T-Waves can penetrate approximately two cumulative inches of clothing.



For a bullet to be instantly effective, it must hit a vital organ such as the heart or brain. Similarly, chemical sprays and pepper sprays must hit an assailant in the face -- no easy task in fast moving confrontations or windy environments. However, the AIR TASER can be used more effectively and with less training than other non-lethal weapons. In fact, the TASER is the Los Angeles Police Department's weapon of choice for those on PCP and the mentally deranged.

APPLICATIONS OF TASER TECHNOLOGY

The AIR TASER system is an ideal tool for the military police and peacekeepers. Imagine the results in such hostile environments as Haiti, Bosnia and Somalia. No longer would a soldier have the critical choice of firing an M-16 or not firing in a dangerous situation. The AIR TASER would simply add the proper instrument for the peacekeeping mission without removing the option of lethal force.

The challenges of modern day warfare and peacekeeping missions are also common to the law enforcement community, particularly in light of the ever increasingly dangerous and litigious times. The streets of America are armed with extremely powerful and efficient weapons and present a serious threat to public safety and officer safety. Often, these threats come from individuals who may be unstable, chemically altered or otherwise extremely dangerous. Apprehension is required, but the methods of apprehension are under the careful and strict auspices of excessive force. Moreover, just as there is a low tolerance for American casualties in warfare in our society, the same holds true for use of deadly force by law enforcement.

Law enforcement could use the advanced AIR TASER technology for street confrontations, chase and apprehension, temporary restraints (used either on the street or during incarceration), suicidal

individuals with weapons, control of individuals, breaking up riots in prisons and jails, crowd control and hostage/barricade situations. Moreover, citizens themselves are using lethal weapons against one another to commit crimes in the heat of passion, during domestic violence, gang initiations and drive by shootings. Every year, firearms kill over 35,000 Americans. The availability of a variation of this non-lethal system could save thousands of lives by giving law enforcement and consumers a viable and effective alternative to a firearm. Already tens of thousands of consumers in the U.S. have purchased the AIR TASER system. It was not available to U.S. military and law enforcement by legal agreement until today – February 25th, 1998. Most of the readers are unaware of this situation. However, today begins the opportunity to answer the NDIA's call for effective and inexpensive non-lethal weapons.

With this announcement of the availability of the AIR TASER for U.S. military and law enforcement use, there are now are multitudes of end users available that have vital interest in using this system or a variation of it. This includes the federal prison system, jails, federal and local law enforcement agencies, and the military police and its soldiers. Now there is an opportunity to join security firms, military contractors with secured facilities and the general mass consumer market in using the most effective, safest and inexpensive non-lethal system worldwide. Already, this system is used worldwide in over 50 countries for military, police and civilian use.

AIR TASER, Inc. believes that more research and development is necessary for the future advancement of non-lethal weapons and thoroughly encourages the advancements in this technology. However, it is clearly evident that the military and law enforcement community has largely been denied one of the most successful and effective systems for non-lethality. The availability of this system as an "off-the-shelf" system for under $250 is now. While research and development continues to find the exotic and magic non-lethal bullet, the opportunities to use the AIR TASER should not be ignored now that this system is available for military and law enforcement use.

The AIR TASER system is simple, clean, lightweight, low cost, effective. The system measures less than 7.5 inches, weighs 9 ounces and requires one 9-Volt battery. Its effectiveness for instant incapacitation is 86%, equal in power to a .357 Magnum. An individual can be armed with one complete system at less than $250. It is available with a laser sight. These are exactly the same parameters the NDIA Non-Lethal Conference II set as goals for industry to respond.

Choices must be made. The military and law enforcement cannot continue to wait empty handed for the ongoing spending of money, time, and effort on new and exotic non-lethal systems. The need to arm these soldiers and police officers with an effective and inexpensive non-lethals is immediate. The AIR TASER is available now. Each day that goes by only increases the chances of unnecessary deaths and dangerous exposure to soldiers and police officers for not having the proper tools that are available today.

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Sticky Shocker*

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Jeff Millard, Gregory Niederhaus and Scott Nunan
Jaycor, San Diego

INTRODUCTION

A non-lethal method is being developed to extend the range for effectively electrically stunning a person. Present technology, consisting of stun guns and tasers, is limited to distances of less than 4 meters. The Sticky Shocker, shown in Figure 1, is a low-impact wireless projectile fired from compressed gas or powder launchers and is accurate to a range of greater than 10 meters, sticking to the target with a glue-like substance or with short clothing attachment barbs. The projectile incorporates a battery pack and associated electronics that impart a short burst of high-voltage pulses capable of penetrating several layers of clothing. Pulse characteristics into a human body are approximately 10 amps peak current, 1.0 microsecond pulsewidth, 0.2 joule energy, at a repetition rate of 12-15 pulses per second. These pulse characteristics are electrically safe, being similar to well-established non-lethal electrical shock devices, and will disable individuals or cause extreme discomfort. The projectile design is compatible with conventional 37/40 mm less-lethal weapon launchers. Applicable missions include any stand-off encounter where an individual needs to be temporarily incapacitated and taken into custody without exposing law enforcement officers or military personnel to unnecessary risk. The presentation will discuss the projectile configuration, shock characteristics, compatible launchers, and prototype field demonstration results.

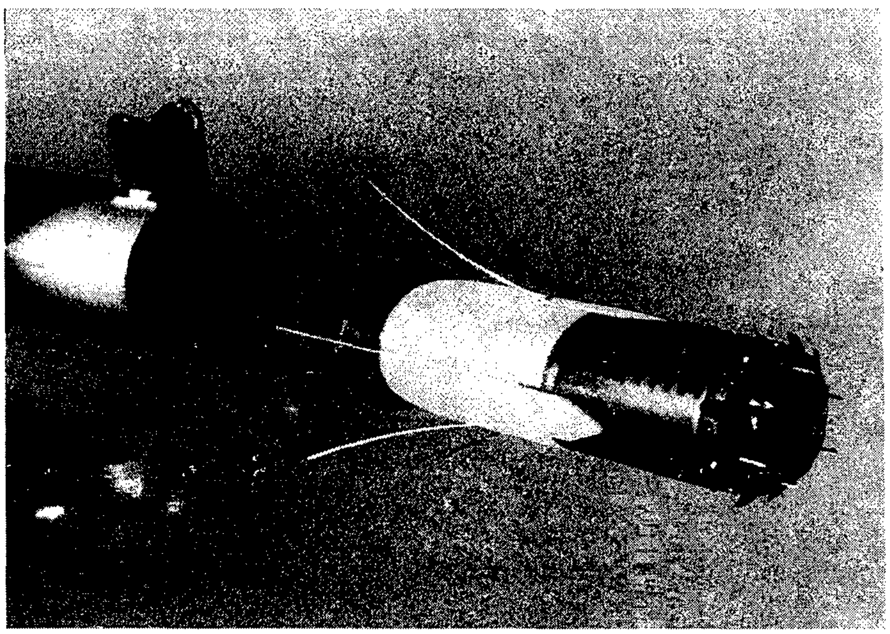

Figure 1. Sticky Shocker is a non-lethal electrical stun projectile.

* "Sponsored by the DoD/DOJ Joint Program Steering Group, at DARPA, and funded as a result of BAA 95/28. The views and conclusions expressed in this document are those of the authors and should not be interpreted as representing official policies, either expressed or implied, of the Defense Advanced Research Projects Agency or of the U.S. Government."

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BACKGROUND

There is a renewed interest in developing less-than-lethal (LTL), less-lethal, or non-lethal technologies. The US and UN military forces are being called upon to police in foreign territories where there is no clear-cut distinction between friend or foe and where foes are often intermingled with friends or civilians. At the same time, law enforcement personnel across the US are faced with the ever increasing challenge of subduing hostile individuals in the face of a litigation-prone society.

Initial interest in LTL technologies came about in the late 1960s and early 1970s, mainly due to civil disturbances, anti-Vietnam war demonstrations and associated student unrest. Two important tools or LTL weapons were developed in this period—the taser (which fires two wire-tethered barbs) and the less lethal kinetic munitions (such as rubber bullets, beanbags, and wooden batons). These are in wide use today.

Law enforcement and military personnel have limited LTL options when opposed by a potential hostile. Recently, pepper spray was added to the arsenal of tasers and kinetic bullets, but like tasers, pepper spray is effective only at close range. Neither pepper spray nor tasers are useful in halting a fleeing suspect.

The idea of the Sticky Shocker came about in response to the challenge to provide an LTL weapon that filled the gap between kinetic rounds and devices that are useful only in close contact situations. The Sticky Shocker concept, as shown above in Figure 1, puts stun gun technology on a wireless self-contained projectile, allowing greater and therefore safer standoff distances. It has been designed to be compatible with current law enforcement and military launch platforms.

DESCRIPTION OF THE PROJECTILE

The Sticky Shocker is a free flying projectile that attaches itself to the target. Figure 2 shows a prototype projectile with three different tip options: barbed, adhesive or combination tip. The projectiles measure 10 cm (4.0 in.) long by 40/37 mm in diameter (~1.5 in.). The Prototype projectiles weigh 135 g (4.5 oz., a little lighter than a baseball). High-voltage electrodes are positioned at the front and rear. The projectiles are ballistically stable, with a center of mass along the cylinder axis and forward weighted. The unit is powered with 6 AAAA batteries.

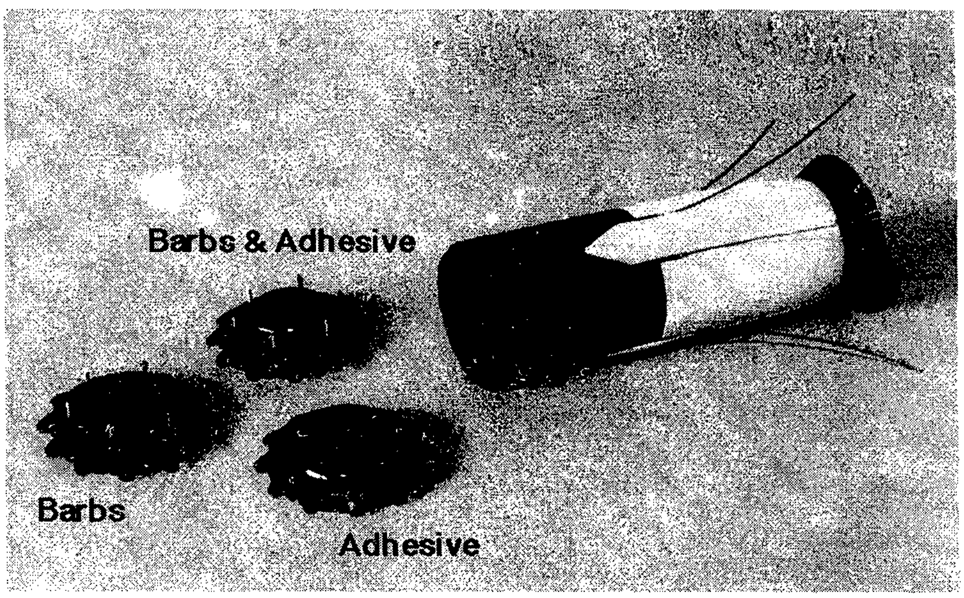

Figure 2. Photograph of Prototype Sticky Shocker projectile with three optional attachment tips.

Figure 3 shows a block diagram for the Sticky Shocker circuit. It features a battery, an arming switch (that initiates pulsing on launch), a timing circuit for auto shut off (and safe handling following use); a charging circuit; and output stage (comprising of transformers, capacitors, transistors, a spark gap, and electrodes).

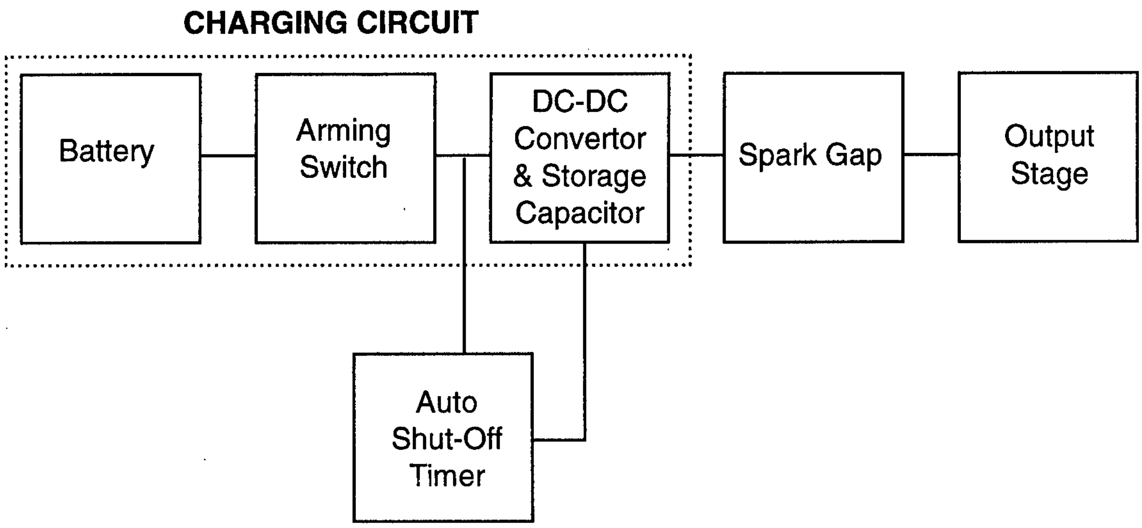

Figure 3. Block diagram of Sticky Shocker electronics.

ELECTRICAL PULSE AND SHOCK SAFETY

There are a variety of commercial pulse-wave devices on the market that claim pulse voltages ranging from 50 kV to over 200 kV. They possess a range of pulse currents, pulse widths, and pulse repetition rates. Claims of extremely high-voltage pulses appear to be marketing hype. While theoretical open-circuit voltages might be 120 kV or greater, in practice a safety air gap to protect against damaging internal breakdown, limits open-circuit voltage to about 30 to 50 kV. An advantage to higher voltages is the ability to penetrate clothing.

The impedance or resistance of the human body changes with the applied frequency. A person has one impedance for a dc current, determined by the conductivity of their sweat glands and pores, and a much different impedance at much higher frequency current pulses (dominated by the person's salt concentration). The human body has an effective impedance near 1 kΩ at the frequency (Hz) of interest for the pulse waveform stun devices (stun guns and tasers). This impedance limits the current. A device voltage divided by the impedance yields the current that can be delivered. Peak currents from 3 to 20 A are possible, and most devices produce peak currents of 4 to 10 A into 1 kΩ loads.

Figure 4 compares Sticky Shocker output to six commercial stun guns. The Sticky Shocker pulse characteristics are similar to high-end commercial units, with a peak current about 10 A and a damped sinusoid waveform with an effective pulse width of about 1.0 μs. With the high repetition rate of 15 Hz, the root mean square (rms) current for the prototype units was about 54 mA. Thus, target incapacitation response should be similar to the high-end stun guns.

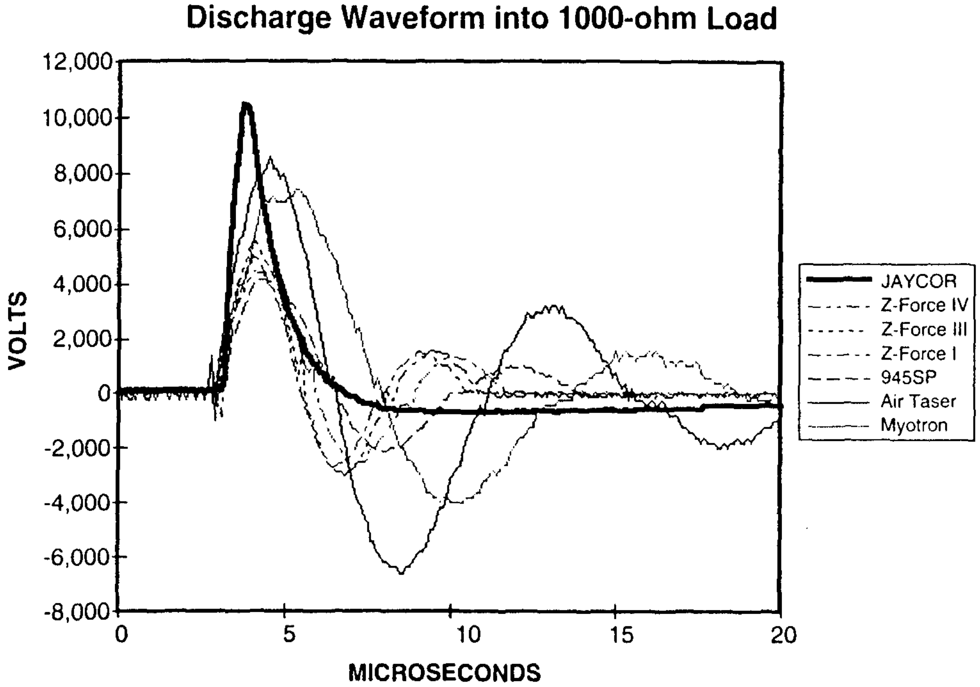

Figure 4. Pulse waveform for Sticky Shocker and other pulse waveform stun devices.

Underwriters Laboratory (UL)[4] and the International Electrotechnical Commission (IEC)[5] have published electrical safety standards for rms current levels for periodic pulse trains—and are directly applicable to pulse wave stun devices like the Sticky Shocker. The standards are based on the rms current, defined as the square root of the average of the square of current. For a series of discrete pulses of arbitrary or complex pulse shapes this is most easily calculated from the measured energy per pulse into a load:

$$\left[I_{rms} = \sqrt{E(J) * \text{ rep rate } (Hz) / R\,(\Omega)}\right].$$

Figure 5 shows measured rms current levels for a number of commercial stun guns. The UL limits for ventricular fibrillation have a built-in safety margin of 2x to 5x, based on a 2-year-old child, while the IEC thresholds relate to the probability of introducing fibrillation in 50% of the population. Typical stun guns have a safety margin of at least 100x. Basically, the short pulse duration of the stun guns has very little effect on heart functioning because the heart has a much longer msec pulse.

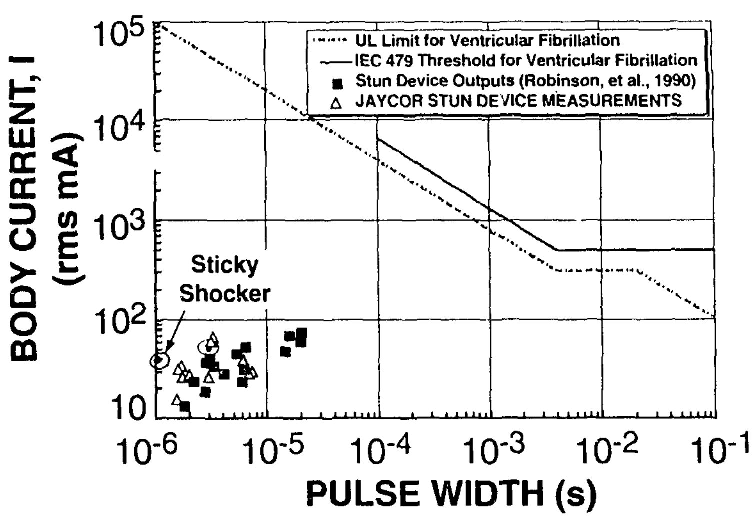

Figure 5. UL and EIC repetitive pulse safety level and rms pulse level for Sticky Shocker and other pulse waveform stun devices.

ATTACHMENT AND IMPACT

In order to incapacitate a target, the Sticky Shocker must attach itself to the skin or clothing of the target individual. Several attachment design concepts were attempted before settling on simple passive designs. One of the promising design concepts involves a tenacious non-toxic glue material, likened to the sticky foam material that Sandia has developed,[6] and another involves a clothing barb attachment scheme. The advantages of these two concepts are that they promise to be cheap and reliable.

Flight tests with the two basic schemes showed excellent attachment at 30 feet to various cloth, leather and nylon materials. Figure 6 shows typical projectile attachments to a cotton T-shirt using barbs (on the left) and an adhesive tip (on the right). The projectile hangs vertical to the target. This configuration allows good contact with the front electrode and rear whisker electrodes. This attachment method allows for maximum spacing of electrodes resulting in a more effective shock over a larger target area.

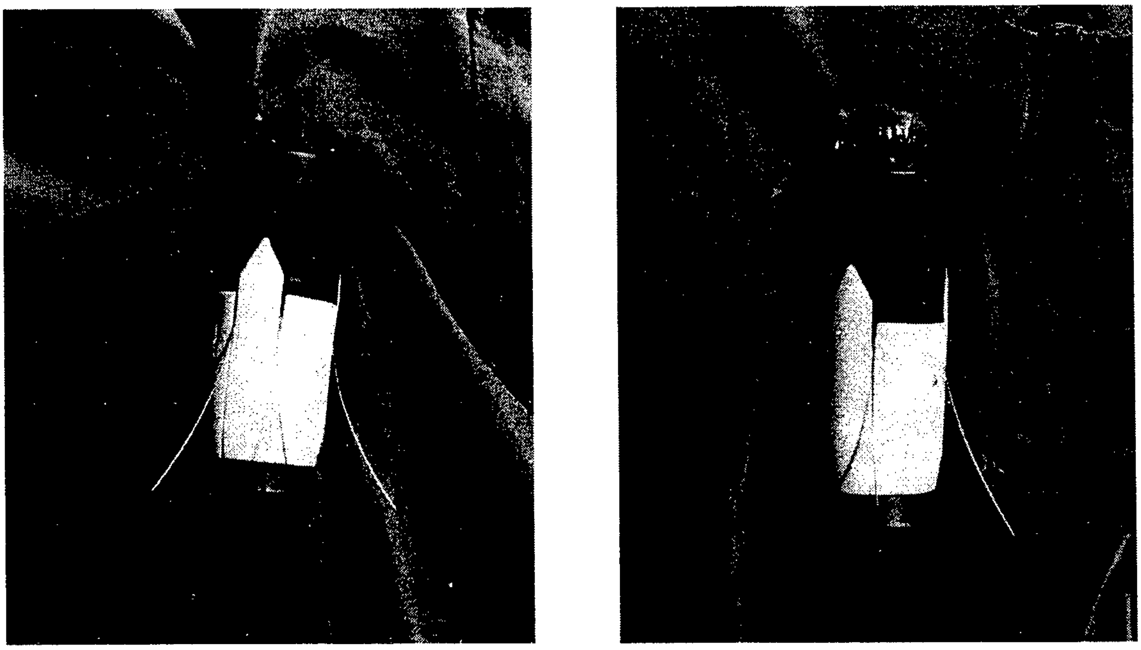

Figure 6. Barbed and adhesive attachments.

To compare the blunt force of the Sticky Shocker projectile to other less-lethal weapons in use the impact force and impulse of a number of weapons were measured using a hydraulic load cell. A hydraulic load cell is a liquid-filled chamber with a lightweight piston, with a known area, that compresses the liquid producing a pressure pulse which is measured with a pressure transducer.

Figure 7 summarizes impact data for the Sticky Shocker compared with other less-lethal impact devices. Both impact force and impulse data are shown. The data are normalized to a 37-mm K01 rubber bullet that is in common use in the law enforcement community. The Sticky Shocker impact was only about 70% of the K01 round, was slightly larger than the MK Flex Baton (shotgun bean bag),[7] and was mid-range compared to a variety of police baton types. For impact trauma, the Sticky Shocker is as safe as other less-lethal weapons in present use.

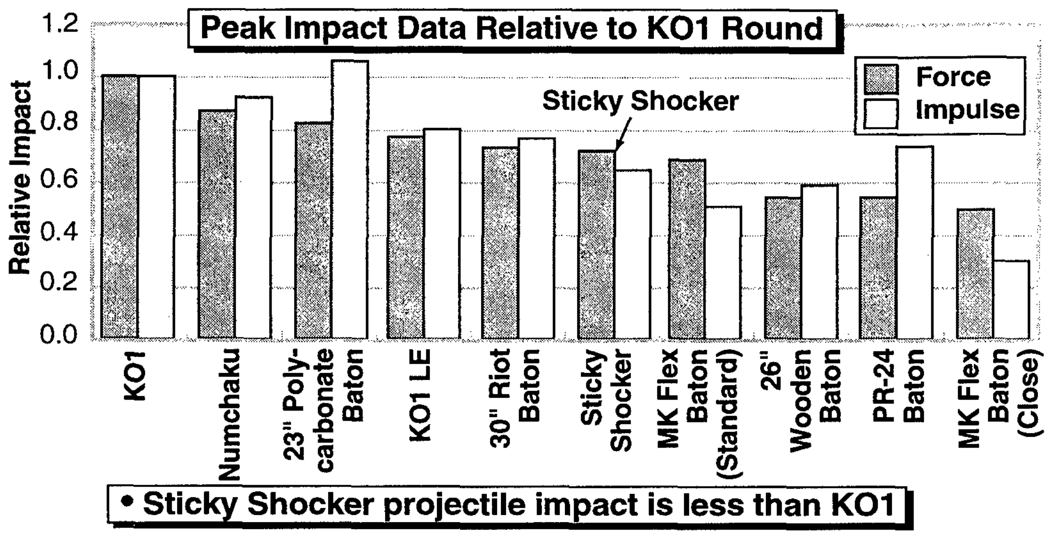

Figure 7. Representative impact/impulse from blunt trauma less-lethal weapons and the Phase One Sticky Shocker demonstration projectile.

USER DEMONSTRATIONS

Within the development phase, Sticky Shocker was demonstrated at User Evaluation presentations. These demonstrations showed that the Sticky Shocker: could fly to a target at 30 feet, attach, turn on and turn off automatically; could shock through a layer of leather and clothing; and finally that the Sticky Shocker could be fired from various currently used military and law enforcement weapons, such as those shown in Figure 8. It appears that, with additional development, the Sticky Shocker could operate at ranges well beyond 30 feet.

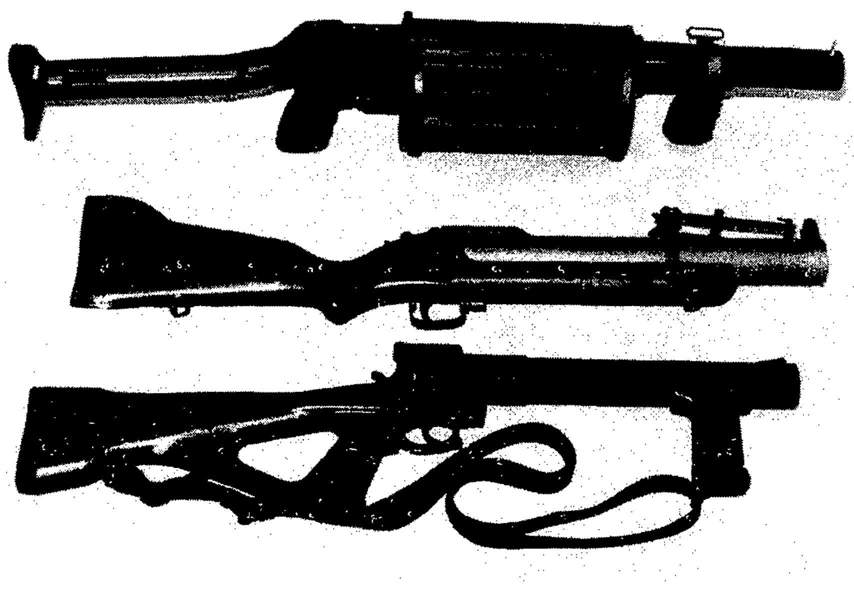

Figure 8. Sticky Shocker is compatible with conventional, military, and law enforcement weapons.

CONCLUSION

The Sticky Shocker projectile shows promise as a new non-lethal projectile. The projectiles produced in the development phase were accurate, stuck on impact, and produced electrical pulses through clothing. Efforts are focusing on further refinements to the manufacturability, and field tests of production units. Manufacturability means that the cost to produce is minimized, that the projectiles are robust (feature a long shelf life and operate through extremes in the environment), and that they are easy to use (load and shoot). The Sticky Shocker projectile is compatible with many existing military launch platforms and in a form useful to law enforcement personnel. The Sticky Shocker projectile adds a new option to non-lethal technology.

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A NON-LETHAL ALTERNATIVE TO ANTI-PERSONNEL LAND MINES

Using Proven Technology

by

James F. Mc Nulty

Anti-Personnel Land Mines cause thousands of civilian deaths and severe crippling injuries for many years after the mines have been abandoned by forces previously at war or who were trying to protect their territory from aggressors. Many of those innocent victims are children. Even when forces try, finding all of these deadly booby traps is nearly impossible. The public concern about the high number of unnecessary injuries and deaths from these mines has resulted in an international treaty to ban lethal Anti-Personnel Land Mines. The United States has not yet agreed to this treaty due to concerns about security in Korea. However, most military forces see the continuing need to deny enemy access to areas without committing large numbers of troops.

SYSTEM CONCEPT
NON-LETHAL, MULTIPLE TASER, AREA DENIAL DEVICE.

Tasertron has taken its well proven, non-lethal police taser weapons and a land mine housing and mine deployment system that will be produced by our teaming partner PRIMEX Technologies and configured them as a Non-Lethal Taser Area Denial Device, similar to an anti-personnel mine. It would contain multiple, independent, standoff incapacitation devices that, when activated by any one of a number of currently available sensors, can temporarily incapacitate, without major injury, a number of subjects, including those wearing soft body armor. The Taser works well even in heavy rain as proven at a Demonstration of Quickly-Fieldable Non-Lethal Devices/Munitions, for the Dismounted Battlespace Battle Lab at Fort Benning Ga. This took place at an outdoor MOUT site in heavy rain, in December of 1995. The very low power, high voltage signal, will also penetrate a combined 2 inches or more of clothing.

To assure that short circuits, due to misses, or low voltage, due to body hits, cannot disable or degrade other dart sets, the Taser Area Denial Device will consist of seven or more independent Taser modules. Their replaceable cartridges are installed in separate firing bays over a 120 degree area, facing the expected threat. They will be mounted in a 2-3 inch thick circular plastic mine housing with a diameter of 12 to 18 inches. Each quick change Taser cartridge contains its propellant and 2 lengths of high voltage wire with contacts that touch the high voltage contacts in the firing bay. The other wire ends are tipped with small barbed darts. All of the Taser circuits will be activated and the cartridges fired simultaneously when the device is triggered by any of a number of existing sensors that could be used to detect an intruder at 70 to 80 percent of the maximum range. When triggered, a coded alarm signal will also be sent to nearby troops. The troops would then proceed to the site to capture the incapacitated intruders and secure the area. The controlling troops can also utilize the alarm circuitry receiver to remotely control the Taser device (on or off or deactivated) via secure encrypted codes. After securing any prisoners the Non-Lethal device can be quickly reloaded and rearmed in the field by the security troops.

Feasibility:
While more expensive than crude land mines initially, the Taser device does not destruct.

It is field reloadable and can be reused for years to reduce costs. The system uses proven technology and existing well proven devices and components that are in current military and police use. These include the Taser circuitry and cartridges with 18 years of field proven safety and effectiveness and various military intrusion detectors, remote radio control systems, and long life batteries. These are utilized in a unique new configuration mounted in a new plastic mine housing.

MISSIONS

Contribution of the Taser Area Denial Device to Mission Accomplishment:

- It would eliminate casualties of non-combatants.
- It would reduce the number of troops required to maintain the security of an area.
- It could protect Anti-Tank mines from removal by infantry.
- It would stop an intruding enemy force or delay a major mass attack.
- It would give our troops early warning of an attack.
- It would prevent accidental death or injury to our troops.
- It would permit the capture and interrogation of enemy troops.

Security and Area Denial: The Non-Lethal Taser Area Denial Device is especially useful in **Low Intensity Conflicts** and **Peacekeeping** operations where there are many civilians in the area or where it may be difficult to distinguish friend from foe. It will not permanently harm either friend or foe. It can also be deployed along defensive line perimeters or around Anti-Tank mine fields and will prevent enemy infantry reconnaissance troops or raiding parties from penetrating our lines. It will hold them for capture and will automatically alert nearby troops via radio or satellite. In the event of a mass attack the Taser devices will incapacitate most of the forward line of the enemy (**and any enemy troops that touch the incapacitated troops**) and will send an alarm signal to our troops. The Taser mines will also instill strong fear into any remaining troops due to the human's inherent fear of electricity. This will give our "ready troops" time to respond and even counterattack without resistance by the enemy's incapacitated forward line of troops.

Peacekeeping: In peacekeeping or disaster relief missions the Taser Area Denial Device can also be used to secure storage areas as well as troop facilities and will deter looting or sabotage. It will permit the capture of looters or saboteurs without injury to either the culprit or the security forces. The non lethal Taser Area Denial Device can also be deployed to keep opposing forces within their assigned areas to help prevent conflicts while using minimum force.

Withdrawal: The Taser devices may be used to prevent subjects from following our forces when they are withdrawing from an area. After the withdrawal is complete the non-lethal Taser Area Denial Devices may be deactivated from a remote position to prevent accidental triggering by civilians.

TECHNICAL

The proposed proprietary device is a non-lethal alternative to the Anti-Personnel Landmine. The device would cover a radius of 15 feet (30 feet possible) and could be triggered by various existing mine sensors such as infared motion detectors, trip wires, pressure plates or a combination of these.

The Taser uses a small low voltage battery and a relaxation oscillator to generate a very low power (about 0.3 to 0.4 joules), high voltage (50,000 volt) pulse of very short duration (4 to 6 microseconds), the pulses are repeated at 8 to 24 pulses per second. The amount of power that can be generated by each Taser device is physically limited by the energy storage capacity of the inductance of the oscillator transformer and, once designed, cannot be changed. This very low, 0.3 to 0.4 joule power level is about one thousand (1,000) times lower than the 300 to 400 joule level of the common heart defibrillator.

The electronic pulse will temporarily incapacitate anyone within an inch of the darts by overriding the brain's signal to near surface motor control nerves, causing uncontrollable spasms of the motor control muscles resulting in temporary loss of the subject's motor control functions. The subject will fall and temporarily be incapacitated. The subject remains conscious and alert but cannot control his muscles. A timing circuit will permit keeping the subjects incapacitated until they can be taken into custody by nearby troops. After the very low power signal is turned off, the subjects will recover within the hour. The non-lethal Taser device produces no collateral damage and poses no lethal threat to friendly forces or civilians, even if accidentally triggered.

While the Taser output is similar to that of a so called "stun gun" there are two very significant differences. The Taser contactors stay connected to the subjects body or clothing, he cannot pull away as he could from a stun gun. The Taser contacts are also much more widely separated (12 to 30 inches) than the 2 inch contact spacing of the stun gun. This means that many more nerves and muscles are affected by the Taser, causing total loss of motor control and incapacitation regardless where on the body the subject is hit.

The Taser will easily take down a person wearing soft body armor since the high voltage readily arcs through the minute holes in the weave of the armor. Metal trauma plates spread the charge over more of the body, however, it will not penetrate a non metallic trauma plate. The Taser is much more effective than a .38 caliber bullet since it is not necessary to hit a vital organ in order to immediately stop an assailant. Although the Taser device would cause no deaths or injuries if accidentally triggered, it can be permanently shut down remotely when no longer needed.

Implementation :
Our concept is to mount 7 or more of our off-the-shelf Taser firing bays into the top perimeter on one side of a standard shaped mine housing made of non conducting material. See figure 4. The separate Taser circuits will be centrally mounted. The batteries will be mounted on the bottom surface of the device. The firing bays will be reversed from that of the standard Taser so that the upper dart will rise one foot for each five feet of range for the short range unit (10 ft. on long range unit).

The lower dart from each firing bay would propel straight out horizontally. The firing bay would be angled slightly so that the lower dart would hit at a height of about 1-2.5 feet at 15 foot range. This would be the positive lead. The negative lead would be angled to reach a height of 4.5 feet at maximum range. The negative lead would also be connected to an electrode imbedded in the ground (earth). This would provide a contact path from either the upper dart (negative) to the lower dart (positive) or from the lower dart to earth (negative) increasing the take down rate.

In this manner the Taser device could take down a crawling or crouching soldier (from earth to a single positive dart) or a standing soldier (from positive dart to upper negative dart).

The area denial device could take down multiple subjects that approach at the same time. See Figure 1. The subjects will be disabled for the duration of the applied power plus at least a few minutes after the power is turned off. Therefore, the long life batteries controlling the Taser circuit will be configured to run for a minimum of 10 minutes (variable depending on battery size), with 1 second breaks every 10 seconds to allow the subject to breath freely under worst case conditions. When triggered, the mine would launch 7 or more dart pairs in multiple directions over a 120 degree arc at 20 degree angles (10 degrees for high density or long range devices) on the area facing the expected intrusion. See Figure 3.

Long range or high density devices could be assembled by stacking two of the 2-3 inch thick 20 degree deployment Taser devices so that one disc is automatically offset radially by 10 degrees. This would provide twice the number of dart sets, each offset by 10 degrees from the next dart set. In this case the upper disc and half of the lower disc must be above ground.

Safety (Lack of Lethality):
The Taser device has been proven safe and effective in over 18 years of police use by more than 400 major law enforcement agencies in the United States. The Taser has also been proven safe by extensive studies and testing by the Medical Director of the U.S. Consumer Product Safety Agency (a federal agency) and other safety agencies. The Taser is so safe it is used by universities such as University of Southern California, Duke University, University of Cincinnati, Black Hawk College as well as at very crowded airports. It is also so effective it is used by many SWAT teams and by the U.S. Department of Justice.

Tactics and Emplacement & Withdrawal Techniques:
Tactics for this device would be the same as for standard perimeter mine deployment except that troops must be maintained near the "minefield" to capture the incapacitated intruders. The number of troops would be determined by the tactical deployment situation, but would be less than the number needed to secure the area without the non-lethal Taser devices or without mines.

The device would use modifications of current deployment systems and it would be deployed in the same manner as current mines. The Non-Lethal Taser Area Denial Device, however, must be deployed so the cartridge firing bays face the threat area and are above ground The devices would be under control of nearby troops, who, could reach the area within 10-12 minutes and could activate or deactivate the devices by coded remote control via radio or satellite.

Withdrawal could be accomplished in a number of ways. Our troops may withdraw leaving the Non-Lethal Taser Area Denial Device active to protect the withdrawal. After safely withdrawing from the area the troops can then disarm the devices by remote control. If the threat permits, the Non-Lethal Taser Area Denial Devices may also be withdrawn by deactivating the devices, then remotely commanding the device to transmit it's coordinates or a homing signal to lead recovery troops to it's exact location.

Maintainability:
The only routine maintenance required is to reload the weapon in the field after it has been triggered and to replace the batteries, when they have been depleted by activating the device, or when never triggered, replace at least every two years. The tasks require no special equipment or skills and minimal training.

Countermeasures:
When deployed and well camouflaged the high percentage of plastic and low percentage of metal as well as the use of minimal explosives (only 7 rifle primers per device) would make the Non-Lethal Taser Area Denial Device difficult for the enemy to detect with current conventional mine detectors.

Countermeasures such as the use of physical shields would not be very effective. Metal shields would only conduct the electricity to the subject taking him down (the ground would be the return). The shoulder of the positive dart can be made magnetic to stick to steel shields assuring long term contact. Plastic shields such as small SWAT type shields would not be fully effective since darts are coming from more than one direction and in many cases at least one dart set or dart would probably bypass the shield. Large shields that could block all directions and cover from head to ankle, or the use of very heavy clothing (more than 2 inches thick) would be effective against the Taser but would be clumsy and greatly slow the enemy force. This would make them vulnerable to attack from roving patrols.

As with Land Mines, the Non-Lethal Taser Area Denial Device could be triggered by the enemy by using armored vehicles or flails to clear the area. Unlike dumb land mines each Area Denial Device triggered will independently send an alarm to nearby troops in milliseconds. The number of alarms received would indicate the size and location of the enemy force. As with mines, saturation bombing or high density artillery fire can also destroy many of the devices.

Development: While each part of the system has been demonstrated to work independently, continued development is needed to demonstrate a complete functional system and to develop the actual hardware and tactics for field deployment.

About the Author: The author serves as Vice President of Engineering of Tasertron the exclusive manufacturer of non-lethal Taser police and military weapons. Mr. Mc Nulty is a senior Electronics Engineer with military and aerospace experience. He holds 6 Patents and has a number of published papers. He is also a law enforcement Non-Lethal weapons trainer and an author whose articles on Use of Force, Police Tactics, and Non-Lethal Weapons are published in law enforcement journals and magazines. Mr. Mc Nulty is a former sworn police officer and also served in the U.S. Army Signal Corps attached to the 25th Infantry Division. Mr. Mc Nulty is interested in comments and questions on his papers or articles and can be reached at (909) 340-0896 or Fax (909) 340-0899.

TASERTRON

PRIMEX AEROSPACE COMPANY

80008-71

Non-Lethal Anti-Personnel Area Protection
TASER MINE

TYPICAL CAPABILITIES:

- Integral sensor detects intruder
- 120° forward protection zone
- Mines can be positioned for overlapping coverage zones (mine field)
- 15 to 30 foot range
- High voltage darts are fired from multiple ports on mine over the 120° forward protection angle
- Intruders are immobilized (but unharmed) until high voltage pulses are stopped (under automatic control or by remote operator)

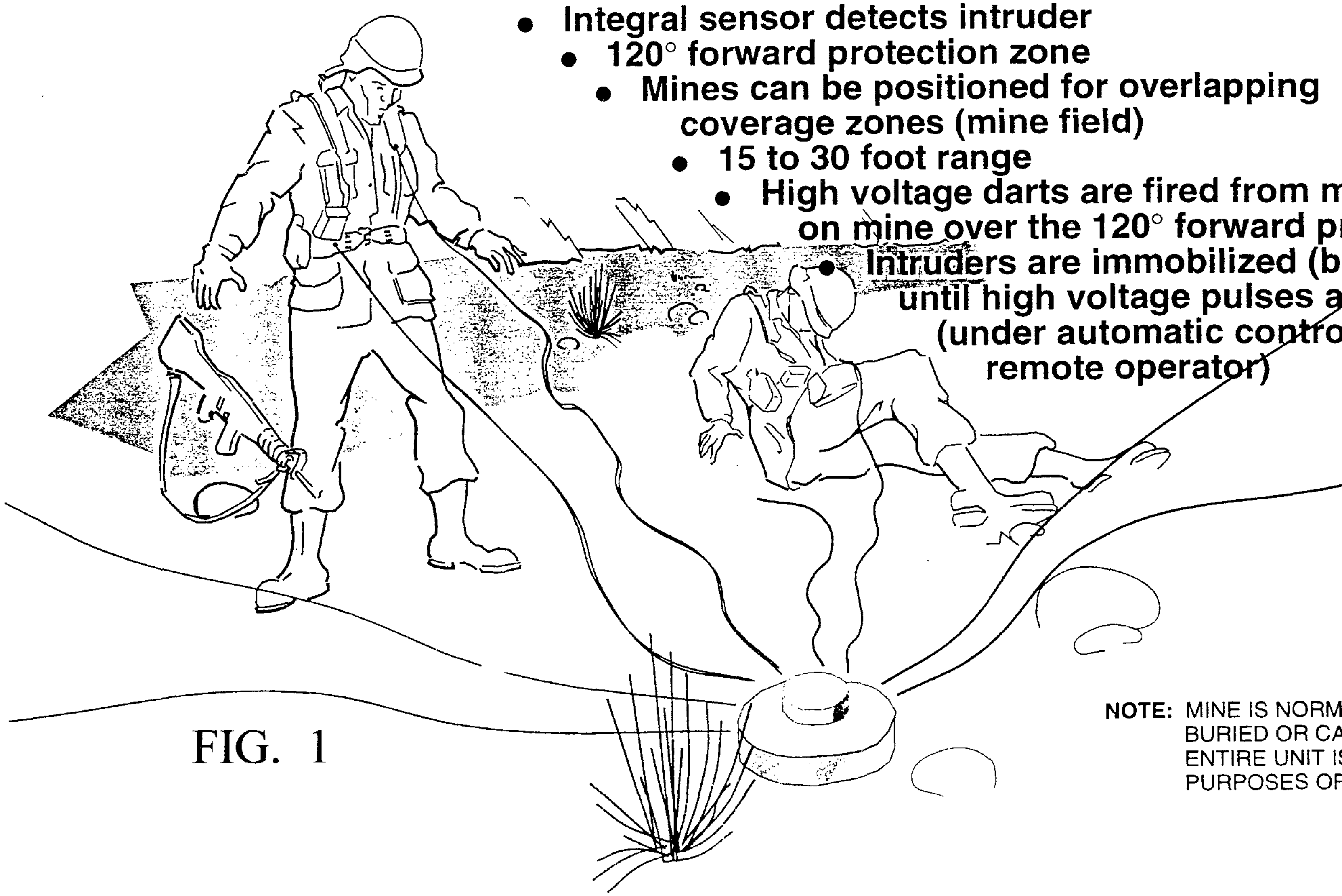

FIG. 1

NOTE: MINE IS NORMALLY BURIED OR CAMOUFLAGED; ENTIRE UNIT IS VISIBLE FOR PURPOSES OF ILLUSTRATION

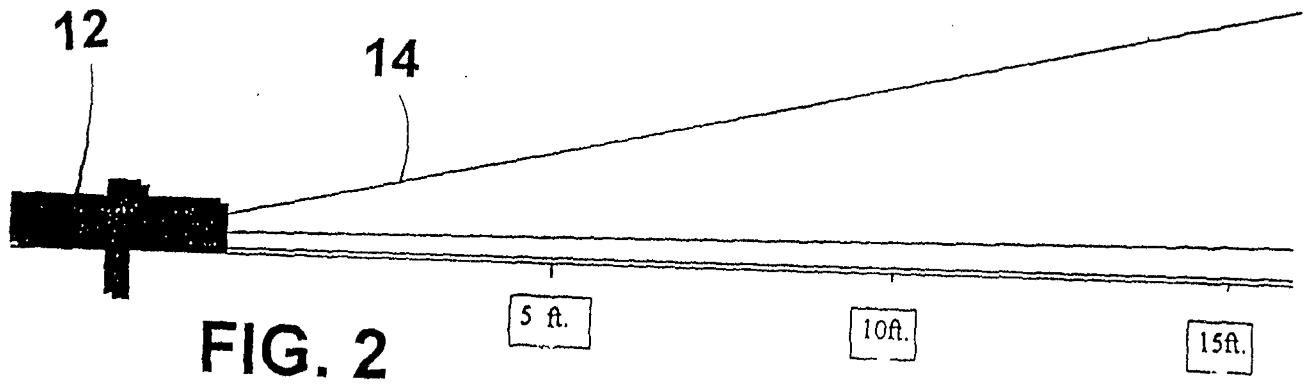

FIG. 2

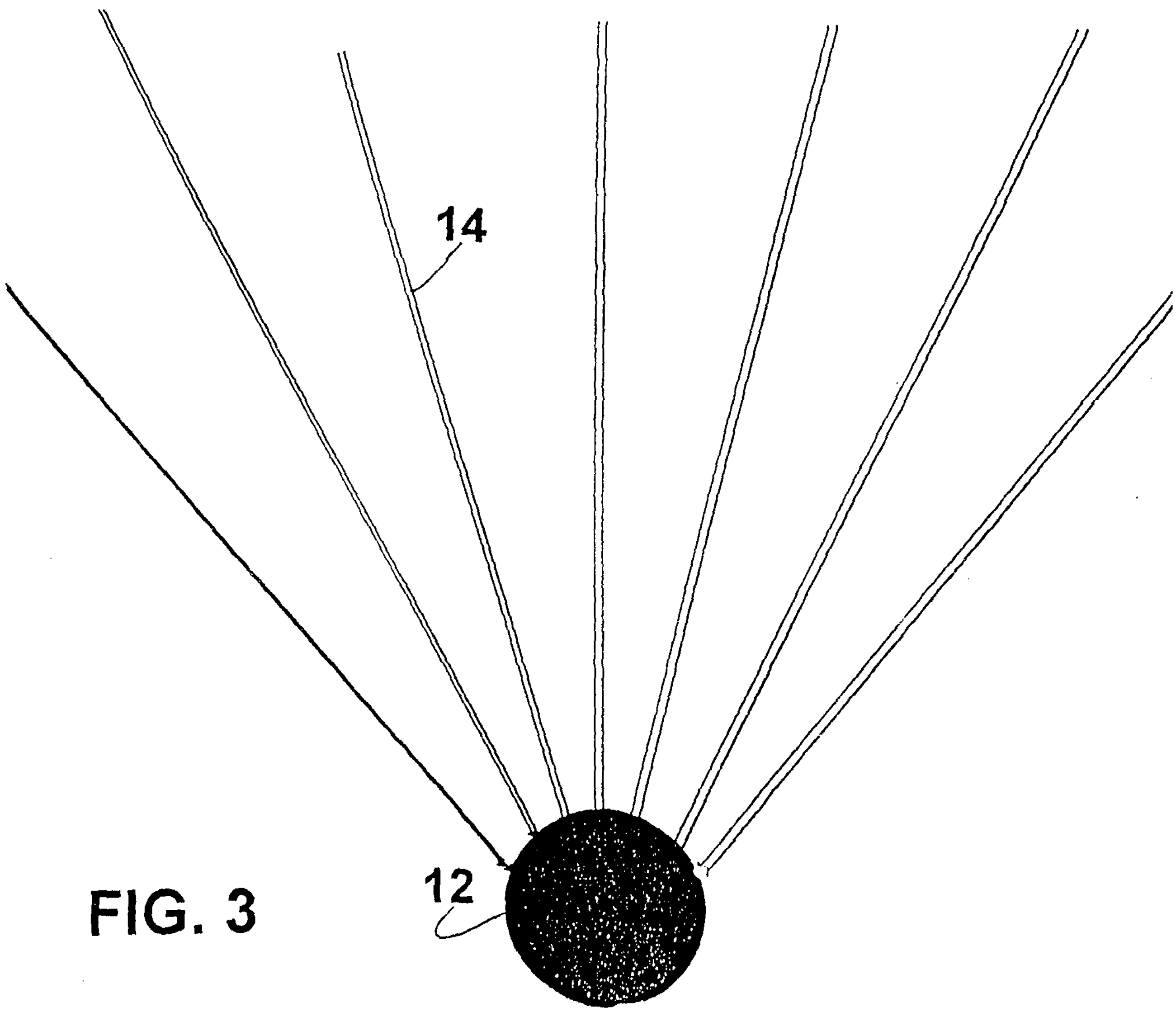

FIG. 3

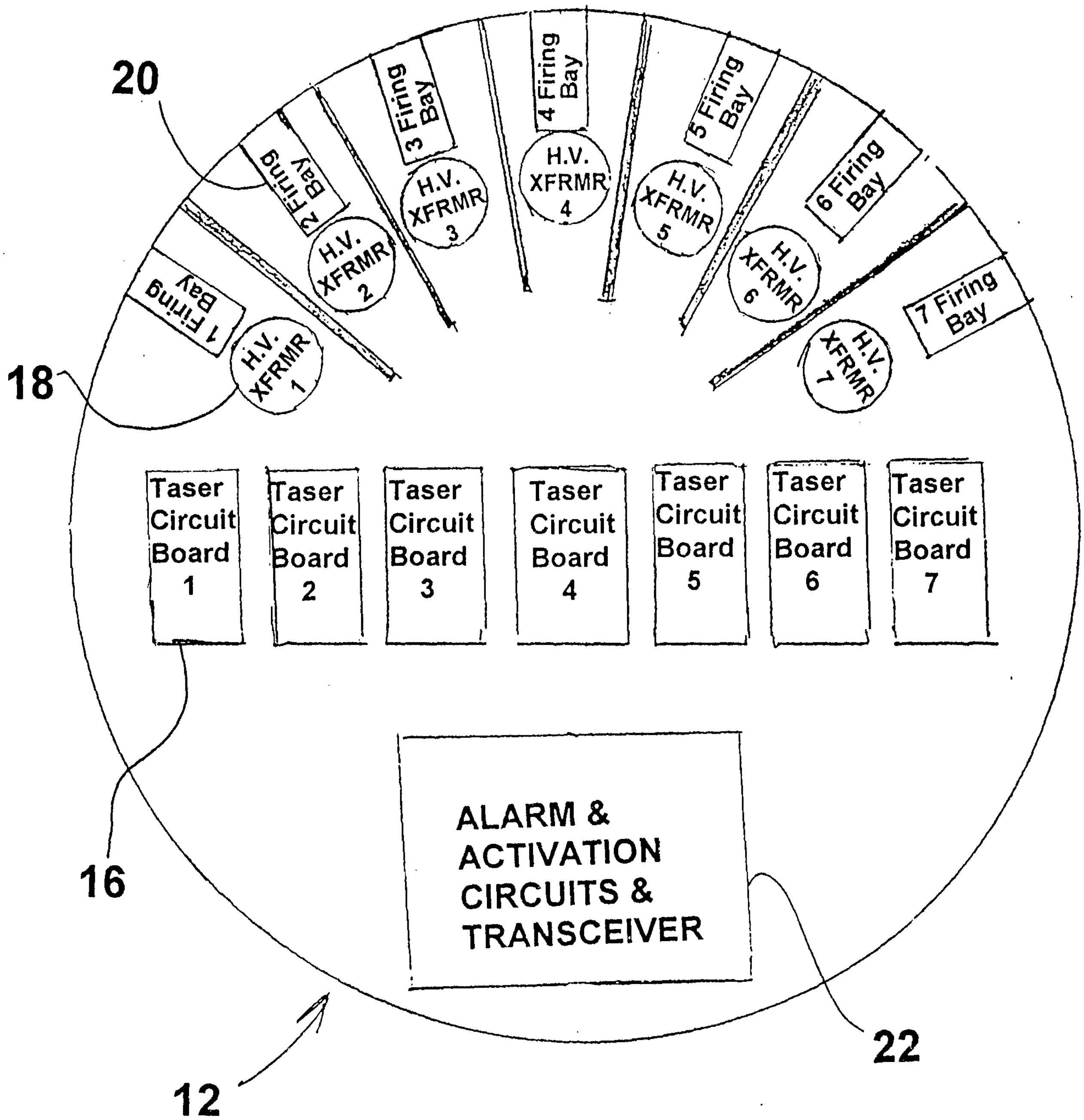
20
18
1 Firing Bay
H.V. XFRMR 1
2 Firing Bay
H.V. XFRMR 2
3 Firing Bay
H.V. XFRMR 3
4 Firing Bay
H.V. XFRMR 4
5 Firing Bay
H.V. XFRMR 5
6 Firing Bay
H.V. XFRMR 6
7 Firing Bay
H.V. XFRMR 7
Taser Circuit Board 1
Taser Circuit Board 2
Taser Circuit Board 3
Taser Circuit Board 4
Taser Circuit Board 5
Taser Circuit Board 6
Taser Circuit Board 7
16
ALARM & ACTIVATION CIRCUITS & TRANSCEIVER
22
12

FIG. 4

Developments in Non-Lethal Payloads for 12-Gauge Shotguns and 40mm Grenade Launchers

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Background

The increasing trend towards US soldiers being engaged in peacekeeping operations has inevitably focused attention on the need to provide the infantryman with a wider range of non-lethal munitions to supplement existing lethal ordnance. Although non-lethal (perhaps better described as less lethal) ordnance is still in its infancy, non-lethal ordnance items have now been fielded, or are in development, in all the major gun calibers available to the infantryman; including 5.56mm, 7.62mm, 12-gauge and 40mm grenade launchers. In this context, 12-gauge shotguns and 40mm high and low velocity grenade launchers (MK19 and M203/M79 respectively) are probably the most versatile weapons for infantrymen to launch non-lethal ordnance from a standoff position. One reason for this is the wide range of distances that can be covered by 12-gauge and 40mm ordnance, another being the relatively large volume, particularly in 40mm projectiles, for incorporating non-lethal payloads.

This paper firstly describes work carried out to develop 37mm and 40mm pepper spray cartridges for law enforcement and military applications respectively. A description is also given of collaborative efforts with two European companies – Nico Pyrotechnik of Germany and Primetake of England – to extend the range of non-lethal payloads suitable for launching from 40mm and 12-gauge delivery platforms.

Pepper Spray Projectile

Delta Defense has developed an improved non-lethal projectile for use in hostage, barricade and tactical assault situations. This work was carried out initially in 37mm caliber and was funded in part by the National Institute of Justice's non-lethal program.

Hostage/barricade incidents pose one of the most difficult situations ever encountered in law enforcement. They call for a measured response to subdue criminals without causing injury to

either the criminal, the hostages or innocent bystanders. Under these circumstances, it is essential that the responding officers should have access to a greater range of improved weaponry to allow them to respond appropriately in the event it proves impossible to end a hostage/barricade incident by negotiation or other peaceful means.

The chemical tear gas agents - CN, CR and CS - have all been used extensively by the military mainly in riot control situations. Pepper sprays (based on oleoresin capsicum) have now largely replaced CS and CN for use by law enforcement in apprehending individuals in one-on-one situations. Unfortunately however, despite all their advantages over the tear gases, pepper sprays have not yet been widely used from a standoff position for crowd control or to counter hostage/barricade situations.

The statement of work for the pepper spray projectile identified the following characteristics:

- Capable of being fired from an existing 37mm law enforcement gas gun.

- Able to deliver the projectile to 100 feet (essential) or 150 feet (desirable) with sufficient accuracy to repeatedly hit a 3 feet x 2 feet target, using only a simple sighting system, by an operator requiring only a minimum amount of training.

- Able to deliver the projectile through a plate glass window or household window glass with a screen or blind, yet be non-lethal at the minimum operational range (50 feet) in the absence of any obstacle.

- Capable of delivering a fine atomized spray of liquid sufficient to fill a volume of at least 1,000 cubic feet within one second of penetrating the above glass targets, or on striking an internal wall or ceiling if entry to the room can be achieved through an open door or window.

Delta Defense is continuing this work under a follow-on grant from the National Institute of Justice with the following additional constraints:

I. The projectile shall be designed and chambered to fire in the 40mm M203 and M79 grenade launchers.

II. The pepper spray container and dispersal system should be adaptable for use in 37mm gas guns.

III. The final product should be ready for production after appropriate tooling development.

40mm Cartridges from Nico Pyrotechnik

Nico Pyrotechnik, based outside Hamburg in Germany, has been developing and fielding 40mm non-lethal ammunition for many years. Nico 40mm high and low velocity cartridges are in service use with German and other NATO and European armies, as well as with law enforcement agencies throughout the world, including the US. All Nico 40mm cartridges comply with the appropriate NATO

STANAGs. A NATO Panel on 40mm Ammunition Standardization, chaired by an ARDEC representative, monitors cartridge interoperability in the various NATO 40mm grenade launchers and ensures that all new HE and training cartridges are ballistically matched to the appropriate US high and low velocity HEDP cartridges (M430 and M433 respectively).

The company offers a wide range of non-lethal payloads in both high and low velocity cartridges, including:

- Visible (white light) illumination (with parachute)
- Infrared illumination (with parachute)
- CS pyrotechnically disseminated
- CS or OC (pepper) in dust form
- Screening smoke
- Signaling smoke (colored)
- Sound & Flash (distraction)
- Training with tracer
- Training with impact signature.

Other non-lethal payloads are currently in development such as providing the ability to mark a person with a visible or fluorescent dye for subsequent identification purposes.

Nico has developed a unique propulsion system for both low velocity (40mm x 46) and high velocity (40mm x 53) projectiles. This design provides greater accuracy (reduced dispersion on the target) and more predictable performance particularly at extreme temperatures. By anchoring the projectile to the high pressure chamber, projectiles are ejected only when predetermined pressures are achieved.

The Nico propulsion system is present on the Diehl GmbH Tracered High Explosive Fragmentation Grenade with Self-Destruct Fuze (40mm x 53 M-DN11 HE-PFF-T) that is about to undergo testing by ARDEC. It also forms part of the Nico Practice Impact Signature cartridge that is currently being considered by PM Small Arms at ARDEC as a cheaper alternative training cartridge than the M918.

The following 40mm sound & flash cartridges have been developed for non-lethal defense applications.

40mm x 46 Cartridge, Sound & Flash, Impact Initiated, for M203/M79 Grenade Launchers

This impact initiated cartridge is designed to function when the projectile passes through a door or window. This considerably enhances the surprise effect and widens the range over which distraction devices can be used beyond that possible with hand thrown stun grenades. The projectile fuze has a safe & arming mechanism that is functioned by projectile spin.

40mm x 46 Cartridge, Sound & Flash, 1.3 Second Delay, for M203/M79 Grenade Launchers

This fixed delay (1.3 seconds) grenade can be used as an aerial distraction device for example to disperse or control rioting crowds. For this application the round would need to be fired to the side of the crowd to avoid causing injury from falling plastic and aluminum debris from the projectile body.

The following 40mm CS cartridges have been developed for non-lethal defense applications.

40mm x 46 Cartridge, Micronized CS Dust, Impact Initiated or Pyrotechnically Generated with 1.3 Second Delay and 15 Second Burn Time, for M203/M79 Grenade Launchers

These cartridges provide the user with a riot control and suppression tear gas CS device fired from M203/M79 grenade launchers. The *impact initiated CS cartridge* is completely smokeless and contains no pyrotechnic components. Penetration of a window or other surface causes the projectile ogive to break liberating the CS dust without any risk of fire. The *pyrotechnically initiated CS cartridge* ignites after a delay of 1.3 seconds and burns for approximately 15 seconds. It generates more CS than the dust grenade but is better suited to crowd dispersal outdoors where the risk and consequence of causing fires are less severe.

In addition, an inert practice (training) cartridge has been designed for the impact initiated CS dust device. This can be filled with chalk or talc to simulate the CS dust and eliminates the need for decontamination of training facilities.

All the above CS cartridges are sufficiently compact to fit in the M203 grenade launcher.

40mm x 53 Cartridge, Micronized CS Dust, Impact Initiated, for MK19 Grenade Machine Gun

This cartridge provides the user with a riot control and suppression tear gas CS device fired from the MK19 grenade machine gun. The grenades are impact initiated (smokeless) releasing CS dust. Again an inert practice (training) cartridge has been designed containing either chalk or talc to simulate the CS dust.

Aerial Distraction and Impact Cartridges from Primetake

Aerial Distraction Cartridges

Primetake has developed a range of 12-gauge birdscaring cartridges comprising a bright flash and loud sound (up to 165dB) or high pitched screech. They are designed to be entirely free from FOD (Foreign Obj. t Damage). This is obviously critically important if they are to be used close to aircraft jet engines where the ingestion of a foreign object can easily destroy turbine blades with catastrophic results. This characteristic means that birdscaring cartridges are ideal for use as aerial distraction and confusion rounds for firing over the heads of crowds to disperse them. They can be fired from standard military unchoked shotguns of any barrel length. The black powder propulsion charges for this application have been replaced by double based smokeless propellants to comply with standard US military requirements to prevent barrel fouling and ensure moisture resistance.

Specifications for the Primetake range of aerial distraction cartridges are given in the table.

The Standard Range Cartridge produces a smoke trail during flight and a loud sound (165dB at 2 meters) with a bright flash at 30-40 meters.

The Long Range Cartridge produces a trail of incandescent particles during flight and a loud bang at 50-60 meters.

The Extended Range Cartridge produces a bright tracer during flight with a loud bang and bright flash at 80-90 meters.

The Screech Cartridge produces a high pitched 'screech' for the duration of its 80-100 meters flight but has **no** bang.

Finally, *the Blank Cartridge* has a 140dB bang but **no** projectile.

Primetake 12-Gauge Aerial Distraction (Birdscaring) Cartridges

PART No.	**PT1000** Standard Range	**PT1001** Screech Cartridge	**PT1006** Long Range	**PT1010** Extended Range	**PT1002** Blank Cartridge
SPECIFICATION					
Top Card Colour	Black	Green	White	Buff	White
Weight	25g	25g	25g	28g	20g
Chamber Length	76mm	76mm	76mm	76mm	67mm
Nett Explosive Quantity	6g	4g	6g	7.5g	3g
Delay Time	1.3 sec	N/A	2.3 sec	3-4.0 sec	N/A
Sound Level	165dB at 2m	N/A	165dB at 2m	155dB at 2m	140dB approx
Range @ 45°	30-40m	80-100m	50-60m	80-90m	N/A
PACKAGING					
Type	UN Approved Cardboard Outer				Cardboard Outer
Dimensions (mm)	340 x 220 x 130				320 x 220 x 115
Quantity per Pack	25 per Inner Box; 200 per Outer Box				250 per Outer Box
Weights	Gross (GW) 4.8Kg; Nett (NW) 4.5Kg; Nett Explosive Quantity (NEQ) 1.2Kgs (approx)				GW 4.0Kg NW 3.8Kg
Shelf Life	2 years minimum in cool dry conditions				NEQ 0.75kg
CLASSIFICATION					
UN Serial Number	0431				0012
Correct Technical Name	Articles Pyrotechnic				Cart. Small Arms
Hazard Compatability	1.4G				1.4S
Transport	Commercial				Commercial
HSE Approval Cert No.	72-Z-00361				01280

Impact Cartridges

Primetake, in conjunction with Delta Defense, is developing a range of impact projectiles (40mm and 12-gauge) based on spherical rubber bags containing powdered metals mixed with lower density powders. The metal powder can easily be adjusted to give a range of weights and velocities to ensure accuracy at all expected engagement ranges. This approach has the advantage that deformation of rubber bags containing metal powders is highly dependent on impact velocity being much greater than that associated with solid rubber sting balls or beanbags containing lead shot. These devices are therefore likely to be less lethal than solid rubber balls or beanbags at short ranges because the impact energy is spread out over a much greater surface area of the body.

NON-LETHAL DEFENSE CONFERENCE/CALL FOR PAPERS

EXPANDED USE FOR THE 66MM GRENADE FAMILY

by

Raymond Malecki and William Rouse

U.S. Army Edgewood Research Development and Engineering Center

In today's environment with decreasing resources and military personnel the U.S. Armed Forces are called upon to meet many world wide challenges. Besides total armed conflict the services are required to perform peace-keeping missions in Somalia, Haiti, and Bosnia, policing at Guantanamo Bay, Cuba and drug interdiction along the U.S.-Mexican border. Many times U.S. forces are subjected to encounters with small armed factions or unruly crowds where containment is the objective, not warfare. Quick developing, threatening scenarios that deal with large groups of civilians make the use of force necessary to preserve order. Differences in culture, language and political alliances can complicate identifying threat from friendly civilians and the decision when or where to use force in a situation. In many instances U.S. forces have only lethal means in which to contain many of these encounters, where non-lethal "containment" use of force or crowd dispersion techniques would apply.

The U.S. Army's Project Manager (PM) Smoke and teams within the U.S. Army Edgewood Research Development & Engineering Center are developing the use of alternative non-lethal payloads for the 66mm grenade. They include stingball, distraction, and Ortho-chlorobenzalmalono-nitrile (CS).

Currently PM Smoke and the Target Defeat Team are designing a 66mm CS grenade by modifying a British L11 CS round. The objective is to product improve the grenade and provide the U.S. Army Military Police an additional capability to be used with their Light Vehicle Obscuration Smoke System. The munition will disperse 23 submunitions and have a range of 60-90 meters. The design team is also investigating an extended range of 150-300m for this grenade. CS affects primarily profuse tearing of the eye. It is conceived to be used in crowd and riot control and for convoy protection.

Another less-than-lethal munition being developed is the 66mm stingball grenade and stingball-flash bang combination grenade. The Defense Technology Corporation under contract with the government is investigating a 66mm rubber bodied grenade. Three types of grenade fills are being developed. One fill consists of .32 caliber rubber balls and another fill consists of .60 caliber rubber balls. A third fill, a rubber ball-flash bang combination is also being developed. It is range is predicted at 60-90 meters at a burst height of 7-12 meters with a aerial burst of 30-40 meters in diameter. Its primary purpose is not to incapacitate but to deter unwanted actions or prevent access to certain areas. A combined stinging sensation upon impact coupled with a sound or flash diversionary effect would induce both physiological and psychological effects.

PM Smoke in response to a need for light vehicle smoke protection created the Light Vehicle Obscuration Smoke System (LVOSS). The LVOSS consists of a launcher system, made up of 66mm four tube dischargers, visual 66mm smoke grenades, an arming/firing unit, wiring harnesses, and elevation and mounting brackets fixed to the turret or roof of High Mobility Multipurpose Wheeled Vehicle (HMMWV) variants. The M7 discharger made from an injection molded plastic (Xenoy) launchs the M90, a

terephthalic acid filled grenade. This fill has low toxicity and is environmentally safe. This fill is designed to obscure in the visual and near infrared region. Each grenade is filled with 3 individual canisters which burn for 14 seconds. The grenade range is approximately 35 meters. Cloud duration is approximately 20 seconds. The grenades are launched in salvos of four providing an initial 60 degree spread of low toxicity smoke and minimum personnel hazard.

In addition to the CS grenade and stingball grenades being developed for use with the LVOSS for the military police, this wheeled vehicle launch system is ideal for launching other less-than-lethal grenades. With the high degree of use of the Up-Armor HMMWVs in policing and security missions, the LVOSS in combination with smoke and less-than-lethal grenades will make situation control more effective.

In addition to wheeled light vehicles, U.S. forces travel within the country policing areas and crowds using infantry vehicles and at times heavy armor. Equipped on many of these vehicles are Rapid Obscuration Systems (ROS) that consist of the standard 66mm grenade launcher system and the high explosive (HE) rapid obscuration grenades they deploy.

These Rapid Obscuration Systems currently installed on U.S. Armored Vehicles are an initial response to the advent of the first smart weapons which significantly decreased vehicle survivability during the advent of the Arab-Israeli Conflicts of the 60s and 70s. First generation ROS installed on U.S. Armored Vehicles were adaptations of the British discharger and their visual screening grenade, the L8. As seeker and guidance technology continued to improve from optically tracked, wire command link guided missile systems to weapons which could acquire targets in the mid and far infrared regions of the electromagnetic spectrum the smoke and obscurant community developed screening materials to extend protection of visual-only screening grenades through the infrared and eventually into the millimeter region .

The type-classified standard family of 66mm rapid obscuration grenades currently consists of the L8A3, a visual red phosphorous screening grenade, the M76, a visual and infrared screening grenade, the M81, a infrared and millimeter (radar) screening grenade, and the M82, a visual screening training grenade. These rapid obscuration grenades typically carry approximately 1.5-2 lb payloads and are deployed from the vehicle's launcher system to a distance of approximately 30 meters forward of the vehicle. They burst typically at a height equal to their launch height. The cloud duration for a single visual screening phosphorous grenade is approximately 3-5 minutes, whereas the duration for a single, infrared or bispectral screening grenade can be anywhere from 20-40 seconds.

The launcher system on each vehicle is comprised of a right and left grenade discharger. The type-classified standard family of launchers consists of the M250/M239, the M257/M243/M259, and the M6. The M250 smoke grenade launcher is comprised of two mirror image six-tube cast aluminum dischargers and two mirror image covers. Its twin, the M239 is comprised of the M250 launcher plus two identical externally mounted grenade stowage boxes and electronic firing switch. These launcher systems can fire any 66mm grenade. The system is capable of firing either one salvo of twelve grenades or two salvos of six grenades each. The dischargers are typically mounted at an elevation of 25 degrees from the horizontal. The discharger tubes are evenly spaced at 10 degrees

apart forming a 50 degree arc for each discharger. When installed, they provide coverage along a 110 degree arc.

The M257 smoke grenade launcher is comprised of two identical four-tube cast aluminum dischargers and eight rubber caps. Its twins, the M259 and the M243 are comprised of the M257 launcher plus additional equipment such as an arming/ firing unit for the M259 and smoke grenade stowage boxes for the M243. These launcher systems can fire any 66mm grenade. The system is capable of firing a single salvo of eight grenades. The dischargers are typically mounted at an angle of 25 degrees above the horizontal. The discharger tubes are evenly spaced at 15 degrees apart forming a 45 degree arc for each discharger and when installed they provide coverage along an arc of 105 degrees.

The M6 smoke grenade launcher is a four-tube rectangular block constructed of E-Glass/Epoxy composite and is painted with resonant Radar Attenuating Material (RAM). The composite material is strong, light and will not corrode. Its shape and coating help to minimize its radar cross section. Its designed use is intended to replace currently fielded six and four tube dischargers on selected current vehicles but is primarily designed to accommodate the needs of future Armored Systems Vehicles now in development. The M6 is easily adapted to a detector system and threat resolution module that comprises a vehicle integrated defense system giving it the capability to inventory and fire individual launch tubes. This provides the maximum flexibility in counter threat performance whereas the other launcher systems can only fire either all or a certain salvo of grenades. The M6 discharger has two banks of two launch tubes spaced 14.5 degrees apart. The M6 has the capability to be used as part of a Multi-Salvo Grenade Launcher (MSGL) system. A MSGL system on an armored vehicle is comprised of two to twenty four M6 launchers and can provide varying screening coverage capability. The maximum screening from a fully outfitted MSGL system is a 360 degrees forward-of-the-vehicle coverage and a 360 degree overhead screening coverage.

Whether the vehicle, is an M1 Abrams tank, carrying the M250 launcher, an M2 Bradley Infantry Fighting Vehicle carrying the M257 launcher, or the new Heavy Assault Bridge outfitted with the M6 launcher, all smoke grenade launchers will accept a 66mm size grenade. This standard discharger size can be utilized for use with other types of grenades to support the U.S. Army's role in operations other than war (OOTW). This is especially important where U.S. forces are deployed where threatening situations develop and the use of non-lethal means would be adequate. To date the U.S. Army lacks the use of any other type of 66mm grenade, other than smoke, to be potentially useful in a non-lethal situation. Grenade loads should be modified to reflect changes in threat. Several foreign countries already have a wide variety of vehicular grenades that perform in multiple mission roles. The French for example have developed the GALIX, a modular self-defense system, for use on various ground combat vehicles. Its launch tubes can accommodate an extended range of ammunition and are loaded with ammunition appropriate to the requirement of a particular mission. The 80mm grenades are fired on a flat trajectory to give an almost immediate response with the ammunition and sub-munition design, giving an excellent effect pattern on the ground. The GALIX system can fire a wide variety of grenades to defend the vehicle against different threats. These include smoke, anti-personnel, illuminating, decoy and training rounds as well as high

intensity sound and tear gas less-than-lethal munitions. The GALIX system is designed to allow reconfiguration of its system to meet future threats. It is capable of being integrated into current or future detection suites allowing additional flexibility in its design.

With launch platforms and proven grenade technology already in use on U.S. vehicles and many chemical and mechanical payloads already developed the role to expand the use of the 66mm grenades could easily be accommodated. Depending on the requirement and the range, the 66 mm HE grenade could be modified to disperse a variety of non-lethal payloads, such as kinetic energy, binding, and acoustic devices. Kinetic energy devices could disperse soft/hard projectiles and slippery fluids. Binding devices could send out adhesives or entanglements. Acoustic devices could be used that carry flash/bang, acoustic jamming and infrasound payloads. Illuminating devices could dispense flares. Riot control devices could dispense irritants, odor producing chemicals, calming agents, or gastrointestinal convulsives. Many other potential uses exist.

These non-lethal 66mm grenades could be used to disperse or subdue crowds, keep personnel from surrounding or climbing on patrol vehicles, slow or halt threatening personnel and vehicles, and even incapacitate individuals for capture.

Engineers, military police, infantry and armor personnel would highly benefit from the increased non-lethal capability of their vehicle's ROS in threatening environments in Operations Other Than War (OOTW). Grenades and launcher hardware is currently available to significantly improve vehicle and crew force protection.

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Dahlgren, VA 22448

System: Unmanned Aerial Vehicle (UAV) Non-Lethal (NL) Payload Delivery System

System Concept: A payload delivery system has been developed to deliver NL munitions from selected UAV platform. The system requires an integration kit to mount the dispensing unit to a selected UAV. Several existing NL munitions are being packaged to fit the universal dispenser. Each dispenser can carry up to 25 rounds of munitions. The total number of dispensers mounted on a UAV is determined by the UAV's payload carrying ability. Therefore, the total number of munitions may vary between each UAV platform. The user will be able to choose the number of rounds to be dropped per pass. The number of rounds to be dropped may be changed while the UAV is airborne. Prior to release of a payload the UAV will dispense a meteorological sensor to measure weather conditions which might effect target accuracy. The UAV is then ready to deliver NL ordnance accurately on target.

Technologies: The system integrates two mature technologies: UAV platforms and existing NL munitions. A software routine has been developed to predict the release point to deliver the munitions on target accurately based on weather conditions and location of the UAV relative to the target.

Maturity: A prototype dispenser has been successfully mounted on the Exdrone and Hunter UAV's. An integration kit is currently being developed to mount the dispenser on the Cypher and Pioneer UAV's.
A Tear Gas simulate has been successfully demonstrated from the Exdrone and Hunter UAV's. Other munitions will be manufactured and deployed from the Exdrone and Hunter UAV's by the end of FY98. This system can be used on any UAV with a minimum of 40 lbs payload carrying ability.
The software routine has been substantiated during testing where the munitions were delivered on target (50 meter diameter). The munitions landed as close as 15 feet from the center of target. (Video tapes of both UAV tests are available)

Missions: Antipersonnel: crowd control, area denial, seize individuals.
An ~ateriel: temporarily disable land vehicles.

Employment: A typical scenario is as follows: The UAV NL payload would be used for crowd control during peace keeping operations. The goal is to deny an area to a crowd of approximately 100 belligerents during a daylight extraction of non-combatants by military personnel. The UAV will be loaded with a NL payload and will be orbiting waiting for instructions to deliver the payloads. Upon the Mission Commanders instruction the UAV will dispense a selected number of NL munitions. The Mission Commander can change the number of rounds that need to be fired against the target based on his assessment of the target.

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Assessing the Blunt Trauma Potential of Free Flying Projectiles for Development and Safety Certification of Non-Lethal Kinetic Energy Impactors.

by
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Introduction

The primary performance objective for non-lethal, anti-personnel kinetic energy impact projectiles is to reliably deter or incapacitate without causing injuries that require medical treatment beyond simple first aid or which leave permanent damage. Unlike many lethal weapons, non-lethal weapons must have upper limits (in order to remain non-lethal) for the impact parameters that govern the terminal effects. The development and safety certification of kinetic energy, non-lethal impactor weapons requires documented and testable criteria to ensure that lethality is limited. Presently there are no firmly established, universal design criteria to ensure that the terminal effect will be below the threshold of unacceptable injury against a specified range of the populace.

Predicting the terminal physiological effect of non-penetrating impact by a free flying projectile on a human being is difficult. Projectile properties, the location of impact, the angle of incidence, and the physiology of the target determine the overall effect. Different parts of the human body are notably more susceptible to blunt trauma injury than other parts, thus the same level of impact to different parts of the body can have a vastly different physiological effect. The only variables that can routinely be controlled in advance of impact on a human by a non-lethal projectile are the projectile properties. A better understanding of the combined influence of projectile properties on the mechanism of projectile/target interaction and on the resulting terminal effect will aid in designing projectiles that are effective yet have a low overall probability of being lethal or causing a serious and/or permanent injury. U.S. impact testing of animals by non-penetrating projectiles, and other blunt impact studies such as from the middle 1960's to the late 1980's resulted in insight into the mechanisms of injury by blunt trauma, and proposed criteria. Distribution restrictions on some of the past work made it unavailable to some projectile designers, and no study is known where all of the available data are compared. These data have now been reviewed and correlated in an attempt to derive more meaningful guidelines for the design and proof-testing of non-lethal projectiles. The present paper is based on releasable data from a report prepared by Battelle in 1997 for the Office of Special Technology.[1]

Some of the projectile properties that influence terminal effect are: terminal kinetic energy, terminal momentum, impact contact area, cross-sectional density, shape, and compliance. Many prior studies of the terminal effect of non-penetrating, non-lethal projectiles ignored these projectile properties except for kinetic energy. In two studies, the diameter and mass of the projectile and the mass of the target were used to fit predictive equations to the experimental results of animal testing. In other studies, impacts on animal surrogates (goats, swine, dogs, and baboons) were used to set kinetic

energy thresholds for lethality and severe injury. In other studies, measurements of impacts were correlated to the mechanism of injury and the extent of a blunt trauma injury; however, these did not relate measured impact parameters to projectile properties.

Key Prior Work

A number of studies of relevance are briefly cited to show the type of past work; these are not discussed in chronological order. Cooper et al. related chest deflection to lethality and developed models for predicting chest deflection as a function of projectile kinetic energy, diameter and target mass or chest thickness.[2] Viano, for General Motors, developed a model called the Viscous Model for predicting the likelihood of severe injury to soft tissue from compression due to blunt impact. The Viscous Model is based on the experimentally measured term CV_{max}, described later in the text.[3] Cuadros, working with Viano, has extended the CV_{max} studies to include impacts from commercially-available, non-lethal projectiles.[4] In conjunction with the Institute for Preventive Sports Medicine and St. Joseph Mercy Hospital, Ann Arbor Michigan, Viano had used the Viscous Model to assess the hazards of baseball impacts to the chest and to test the degree of protection offered by commercial chest protectors.[5] Several organizations including the Land Warfare Laboratories[6], the Lovelace Foundation, and the Swedish Research Institute of Defense[7] performed tests, where animal surrogates and/or human cadaver skulls were impacted in various locations by an assortment of blunt projectiles, including experimental and then commercially-available projectiles. The damage produced by the impacts was correlated to projectile energy, velocity and sometimes projectile diameter and target mass. The U.S. Army Biomedical Laboratory at the Edgewood Arsenal developed a four parameter model for predicting the lethality of a blunt impact to the thorax region and for predicting the likelihood of liver fracture due to an impact to the liver region.[8]

The Biomedical Laboratory performed a series of blunt impacts with free flying, non-compliant cylinders on goats. The group related the projectile properties of mass, velocity and diameter with the target mass to the experimentally observed terminal effect for an impact to the side of the thorax over the lungs and for an impact to the side of the thorax over the liver. They noted the terminal effects of each test on a scatter plot of ln WD versus ln MV^2, (where M is the mass of the projectile in g, V is the velocity in m/sec., W is the target mass in kg., and D is the diameter of the projectile in cm). It was noticed that the impacts with similar terminal effect were grouped together and that by drawing two parallel, discriminate lines, these terminal effects could be separated into three distinct groups. These were then defined using the parameter MV^2/WD.[8]

The Edgewood Arsenal work also took data, from several sources, for blunt impacts to other surrogate animals impacted with a variety of projectiles. These data were plotted as ln WD versus ln MV^2, then overlaid with the discriminate lines discovered from the goat testing. It was found that the model agreed well with the independent test data, if certain eccentricities in some of the data points were considered.[8] Edgewood Arsenal also fit a probability function to the data plotted as ln (WD) vs. ln (MV^2), for non-lethal and lethal impacts to the thorax.[8] The probability function is used to predict percent chance of death due to an impact to the thorax based on the parameter MV^2/WD. For example, an impact in the lung area with an $MV^2/WD = 1000$ has a predicted probability of lethality of only 1%, however, an identical impact over the liver area is in the zone were 50% percent of impacts caused liver fracture in the tested goats.

The previously mentioned Viscous Model is based on studies of steering wheel compression of the chest of unembalmed cadavers in simulated automobile accidents. Viano noted that damage to the heart was a function of two parameters: the percent compression that occurred, and the rate at which the compression occurred. He noted that small compression of the chest could cause fatal damage to the thoracic organs when the compression occurred over a short time period. He called this the viscous effect and said that during slow compression of the chest, the body tissue can deform without damage. However, when the compression occurs quickly, the tissue cannot deform rapidly enough to prevent damage. Studies performed with cadavers, animals and a Hybrid III anthropomorphic simulator led to the development of the term CV_{max}. This is the maximum of the instantaneous product of the fractional chest compression, C, times the rate of compression, V. When the rate of tissue compression exceeds some threshold, the damage mechanism changes from one consisting of a simple crushing/shearing to one involving a more complicated visco-elastic response (rate-dependent response). This is very similar to dynamic loading where all loading on a structure will have the same effect if the product of peak pressure and total impulse is constant. Thus, a dynamic load can have the same effect as a much greater static load. An analogy is easily made to CV_{max} were V is analogous to peak pressure and C is analogous to total impulse. Therefore it is reasonable to assume that CV_{max} will also correlate with fracture of the ribs.

Viano correlated the damage to human cadavers and surrogate animals by a blunt impact with the experimentally measured CV_{max} from identical impacts on a Hybrid III anthropomorphic simulator. He concluded that impacts to the chest which produce a CV_{max} equal to 1 m/s had a 25% chance of causing severe damage to the thorax, and a CV_{max} of 1.3 m/sec. to have a 50% chance of causing severe damage to the thorax. Viano considers a CV_{max} of 1 m/sec. to be a threshold for human tolerance to blunt trauma of the chest.[3] An initial attempt to measure CV_{max} for the impact of several non-lethal weapons have been made, however, there is a large variation in the measured data.[4] It does not appear that a suitable method to accurately measure CV_{max} for non-lethal projectiles has been found and substantiated. This theory, though is supported by other work, and shows promise.[1,2,7]

In fact, Clemedson recognized (in the late 1960's) the significance of the rate of compression on the severity of injury. Studies with rabbits exposed to primary blasts revealed that the rate of chest compression has a much stronger influence on the extent of pulmonary injury than the amplitude of compression. It was noted that for chest compression (in rabbits) occurring at less than 15 ft/sec surface speed, compressions as great as 20 mm caused no pulmonary lesions. However, pulmonary lesions of increasing severity occurred for 5 mm compressions when the velocity of compression increased from 15 ft/sec. to 35 ft/sec. When the rate of compression was increased to 50 to 65 ft/sec, a 5-mm compression had a 50% chance of lethality. Compressions of 5 mm in excess of 65 ft./sec. had a greater than 50% chance of lethality. If the amplitude of compression was increased to 15 mm, a compression velocity of 65 ft/sec. produced 100 percent lethality. A further increase in the amplitude of compression to 20 mm at 65 ft/sec. had a high probability of being instantaneously lethal.[8]

It is interesting to note that if you calculate CV_{max} for the case of 50% lethality, (using a rabbit chest dimension of 75 mm and assuming a constant velocity for the compression), you get $CV_{max} = 1.3$ m/sec. This agrees with Viano's estimate of 50%

chance of severe injury for CV_{max} = 1.3 m/sec. The value 75 mm is the approximate chest dimension of some New Zealand rabbits used in a study by Lau et al.

Cooper and Taylor also made observations about the rate dependence of tissue damage due to blunt trauma compression. They explained this phenomenon of additional injury, beyond that caused by the crush mechanism, in terms of longitudinal pressure waves which they called stress waves. They said the stress waves are propagated in front of, and beyond the points of compression, when the rate of tissue compression exceeds some threshold. They measured overpressure in the right ventricle caused by the stress wave immediately after impact and the subsequent compression of the heart, by the deflection of the rib cage, when swine were impacted in the thorax with 140 gram 3.7 cm diameter projectiles at 30 to 64 m/sec. They also measured the depth of chest deflection and calculated the velocity of deflection using high-speed photography. Cooper fitted two equations to these data, one for calculating normalized chest deflection and one for calculating actual chest deflection. The two equations for predicting chest deflection are based on terminal kinetic energy and the diameter of the projectile and the mass or chest thickness of the target.[2] In another set of tests swine were prepared four to five weeks prior to the tests by surgically attaching small silver spheres to several locations on the heart and aorta. Cine and flash radiography were used to measure, with millisecond resolution, the displacement and velocity of displacement of the animals' hearts following impact.[9] Cooper did state, "Most impacts at 'high' velocity (say > 30 m/s) are with projectiles of low mass resulting in short duration, small displacement of the body wall at high velocity. Under these circumstances, stress waves may contribute significantly to the injury mechanism."[10] Cooper also stated that the stress waves produce injury at the micro-vascular level in regions of discontinuity such as the air/tissue interfaces of the lungs, stomach, and intestines.[10] This may be the effect responsible for the formation of pulmonary lesions from exposure to a primary blast.

Some Comparisons

Cooper's model for chest deflection can be related directly to the Edgewood Arsenal model. Multiplying the Edgewood Arsenal parameter MV^2/WD by ½ and dividing by 1000 g/kg converts it to the variable E/WD in Cooper's equation for calculating normalized chest deflection = $0.4\left(1\text{-}e^{-0.95(E/WD)}\right)$, where E = kinetic energy of the projectile in joules, W = mass of the target animal in kg., and D = diameter of the projectile in cm. This allows chest deflection, calculated as a function of kinetic energy and projectile diameter, to be related to the predicted lethality using the Edgewood Arsenal model. The implication of this is that if the ratio of kinetic energy, KE, to diameter, D, is held constant for a series of projectiles, they will all have the same predicted lethality by the Edgewood Arsenal Model and the same predicted depth of chest deflection by Cooper's model. Two questions to ask are: Under what conditions could this be valid? Do other models of lethality support the contention of identical lethality when KE/D is held constant?

The first condition that must be met for either of these two models to be valid is that the projectile impact be non-penetrating. This places limits on kinetic energy that is projectile dependent for a given target. The projectile properties of cross sectional area and density, shape and compliance influence the tendency of a projectile to penetrate. Cooper's expression for normalized chest deflection approaches a maximum of 40% as the ratio of E/D increases, therefore correlation with the Edgewood Arsenal model should

not be made near values of 40% relative chest compression. Also the impacts should be in a region were they produce a non-lethal outcome. It is meaningless to compare lethal impacts, as lethality does not have a relevant severity scale. Next, the meaning of KE/D must be considered.

With no other constraints, the constant KE/D means very little. At any given KE the value for momentum can vary widely. At constant KE, when momentum is maximized and the terminal velocity drops below some threshold, whole body displacement of an unrestrained target will occur before significant tissue damage by compression occurs. On the other hand, when momentum is minimized, the inertia of the projectile becomes so low that the projectile is rapidly stopped by the target, thereby delivering all its kinetic energy before any significant displacement of the body wall occurs. Therefore, kinetic energy thresholds are probably only valid within a specified range of momentum values.

Momentum is directly related to the impulse from the impact and the duration of the target/projectile interaction. The impulse and duration of the impact influence the mechanism of target/projectile interaction and thus the physiological response to the impact. At a constant energy, increasing the momentum of the projectile increases the impulse and the duration of the impact. The greater impulse means that the impacted tissue is exposed to pressure under the projectile for a longer period of time. The greater momentum also means that the duration of the impact is greater, thus the transfer of energy from the projectile to the target is spread out over a greater length of time. This favors injury by a simple crush and shear mechanism. As the momentum is decreased, at constant KE, the impulse and the time of projectile target interaction decrease. This means the tissue is compressed for a shorter length of time and that the same amount of energy is transferred to the target in a shorter length of time. Since energy and work have the 'same units', minimizing momentum maximizes the power, which is work per unit time, of the impact. This favors injury by Viano's viscous model. Since both models (Edgewood Arsenal and Cooper) were derived semi-empirically from experimental results of blunt impact, and because the mechanism of injury and the efficiency with which energy is transferred from the projectile to the target is largely momentum dependent, these models are most likely only valid for projectiles with similar momentum, kinetic energy and diameter to those used by the two research groups.

Furthermore since the body is made up mostly of water, its viscosity increases as the rate of deformation increases. This has a synergistic effect as the momentum decreases at constant kinetic energy. The increase in viscosity causes the body to apply a greater force of resistance to the projectile. Thus, further decreasing the projectile target interaction time and the impulse with a subsequent increase in the rate of energy transfer from the projectile to the target. This increase in resistance to flow by the body as the momentum of the projectile decreases will cause the actual depth of deflection to deviate from that predicted by Cooper's equation. Cooper's equation says that chest deflection is directly related to kinetic energy. Kinetic energy and work have the same units of force times distance. Since the force is the body's resistance to flow, deflection by the projectile decreases as the resistive force of the body increases. Therefore the two models are also probably only valid when the impact velocity is within the range of velocities used in the testing.

Discussion

From the cited references it is apparent that the physiological effects of blunt trauma are due mainly to two simultaneous injury mechanisms. The first mechanism is crush and shear. This mechanism dominates the injury when the displacement or compression of tissue occurs at relatively low velocity. This low velocity displacement creates injuries by crushing organs and applying shearing forces to arteries, veins, bones, and connective tissues. The second mechanism is the previously described viscous mechanism of damage. Viscous damage is basically crush injury with time dependence. When the crush or compression occurs rapidly, the tissues being compressed cannot deform rapidly enough to relieve the sudden increase in hydrostatic pressure. This results in micro-vascular injury beyond that which would have been expected from a long duration crushing injury of the same displacement. As mentioned, this time dependence is analogous to shock loading of a structure. Additionally, the pressure pulse that develops from the high pressure in front of the projectile, if of sufficient amplitude, will cause further damage as it propagates beyond the volume of tissue that was displaced. The damage done by the pressure pulse, beyond the volume of tissue that is directly displaced or compressed by the projectile, is accentuated in regions of discontinuity such as the air/tissue interfaces of the lungs, stomach, and intestines.[10]

When a non-penetrating projectile hits a body it deflects the body wall, compressing and displacing organs that are in its path. If the deflection occurs very slowly the total amplitude of the deflection can be rather large before any significant physiological damage is done. Also, the pressure under the projectile which is initially low increases in a somewhat linear fashion as the amplitude of deflection increases. For the case of a slow deflection the degree of damage tends to be directly related to the amplitude of the displacement. As the velocity of the displacement increases, the total amplitude of the displacement that can occur before physiological damage decreases and the instantaneous pressure under the projectile increases. The degree of physiological damage begins to deviate from being linearly related to displacement amplitude. At some point as the velocity of displacement and the pressure under the projectile increase beyond a threshold, the physiological damage becomes exponential with respect to displacement. At and beyond this point small displacements of the body wall, that under milder conditions would cause no damage, can cause significant physiological damage.

We need to keep in mind that our interest is in non-lethal impacts that do not cause serious or permanent physiological injury. The impact from a non-lethal weapon thus should not cause damage by the viscous mechanism, as there is a high potential to produce a significant amount of tissue death. The damage by a lower velocity crush and shear mechanism, produced by a non-lethal weapon impact, must be below the threshold at which large vessels are ruptured, bones are broken, and any internal organs are fractured. In order to design non-lethal projectiles that produce the desired terminal effect two things are needed. First, a better understanding of how the projectile properties and the terminal parameters determine the mechanism and the magnitude of the projectile/target interaction is needed. This will allow projectiles to be designed to produce an impact with the desired terminal effect. Second, a better understanding of the physiological threshold to the combined effects of blunt trauma resulting from the different trauma mechanisms is needed. This will allow projectiles to be "tuned" so that their terminal effect falls below the threshold for serious or permanent injury.

To a large extent, the kinetic energy determines the depth of deflection of the body wall. However, momentum also has an influence on deflection depth. This is because the momentum at a given kinetic energy has a strong influence on the duration of the impact. Short duration impacts (lower momentum) cause the deflection depth to decrease due to the viscous effects of body fluids. More important though is the dependence of wounding mechanism on the duration of the impact. Short duration impacts favor wounding (if any) by the "Viscous Mechanism" and long duration impacts favor wounding (if any) by a crush and shearing mechanism. Both these mechanisms, viscous and crush and shear, occur for every impact. The severity of the damage by these mechanisms, at a given kinetic energy, is to a large extent determined by the projectile momentum. The importance of the relation between momentum and kinetic energy was observed from fragmentation studies on goats where the degree of incapacitation from a fragment hit was related to $MV^{3/2}$, which is the square root of the product of momentum and kinetic energy. This is also similar to shock loading where the product of peak pressure and total impulse is constant for an identical effect. High momentum favors crush and shearing, low momentum favors viscous injury. Construction of the projectile can also affect the mechanism of projectile/target interaction. Blunt projectiles spread the initial impact force over a larger area of the target. This helps to decrease pressure maxima, and the possibility of localized viscous injury due to the rapid compression of tissue from the high pressure developed at the tip of the sharp ogive. The blunt ogive also minimizes the likelihood of penetration. A compliant projectile is also beneficial as it helps to increase the projectile/target interaction time and it helps to absorb some of the energy of impact, lowering the pressure under the projectile, which allows for a greater terminal energy, which is beneficial from an aerodynamic point of view.

In order to know why one projectile produces a severe wound and another does not you must know the mechanism of each interaction. The mechanisms of projectile/target interactions can be elucidated from studies of impacts where the results are related to the projectile and not to a potential physiological response. A uniform and instrumented test medium can be used to measure the effect of changing one (if possible) projectile parameter over a range of values. For instance the kinetic energy, diameter, compliance and shape of a projectile can be held constant as the momentum (mass times velocity) of the projectile is changed. Conversely the momentum can be held constant and the kinetic energy varied. Of course, in a similar manner the effects of varying the other projectile parameters can be investigated. The measured data from the impacts can be correlated to projectile properties and later to a physiological response.

Ideally, the physiological response could be predicted using a computer model of a human target. Thresholds resulting from the computer model could be verified with limited animal testing. The instrumented test medium could be a three-dimensional array of pressure sensors dispersed in modeling clay, ballistic gelatin, or a high viscosity oil. Pressure measured as a function of time after impact and location of transducer relative to impact site could be correlated with the degree of deflection and the velocity of deflection measured by high-speed photography. Alternatively, a block of ballistic gelatin could be prepared with a dispersion of micro-spheres containing a die activated by a component in the gelatin. Any volume within the gelatin where the pressure exceeded the rupture strength of the micro-spheres would be made visible by the dye. Knowledge of the

rupture strength of the micro-spheres and the dispersion of the dye in the gelatin could be correlated to projectile parameters and a physiological response.

Recommendations

Future testing of non-lethal projectiles should use advances in materials, computer modeling, and instrumentation to avoid the need for additional animal or perhaps even cadaver testing. Proper instrumentation and modeling would allow greater insight into non-penetrating type, non-lethal injuries. Knowledge of how the physical properties and parameters of a projectile relate to the physiological response from their use against a human target will allow weapons designers to design projectiles to produce a desired terminal effect. The better understanding of the physiology of blunt trauma, that will result from the knowledge of the projectile target interaction mechanism, will aid the in developing safety certification of non-lethal weapons and in setting impact thresholds for weapons designers.

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Vortex Ring Generator

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Abstract

The U.S. Marine Corps Joint Nonlethal Weapons Directorate tasked the U.S. Army to demonstrate a means of quickly converting the Navy MK19-3 automatic 40-mm grenade launcher between lethal and nonlethal modes of operation. The Arn Research Laboratory (ARL) teamed with the Armament Research and Development Engineering Center (ARDEC) to demonstrate a kit for retrofitting to the weapons already stockpiled by all services. The kit enables the weapon to apply flash, concussion, vortex ring impacts, marker dyes, and malodorous pulses onto a target at frequencies approaching the resonance of human body parts. Two goals are to provide a demonstration to the U.S. Army Training and Doctrine Command in 1998 and to transition from technology base research to PM Small Arms development in 2000. This paper describes the concepts proposed for nonlethal crowd control, gaps in technology that inhibit fielding, and proposed approaches to resolution. Organizations in government, industry, or academe with common interests and active vortex ring programs are encouraged to coordinate with ARL to share resources and avoid duplication of effort.

Introduction

Vortices occur in nature as tornadoes, waterspouts, ship wakes, aircraft contrails, cannon smoke rings, nuclear clouds, etc, assuming either a spinning axial or spinning torroid shape. Because of their significant impact on the architectural, aircraft, ship, and motor vehicle industries, research into the mechanisms of formation, propagation, and stability of vortices has been published throughout the nineteenth and twentieth centuries. Serious studies of vortices and vortex motions originated by Helmholtz in his paper of 1858 [1] and continued in the work of Lord Kelvin [2], Hill [3], and others in the nineteenth century and the first half of this century. Many of the modern vortex ring studies and advances in vortex understanding are made possible because of powerful computers coupled with numerical techniques. The field of aerodynamics stimulated vortex studies related to turbulent flow, stabilities, and instabilities, and a description of the status of vortex dynamics is given by P. G. Saffman [4]. Other work [5–7] describes vortex stability research performed in the 1970s by the current Secretary of the Air Force, the Honorable Dr. S. E. Widnall. Additional studies on steady and turbulent vortex rings are given by Fraenkel [8] and Maxworthy [9]. A bibliography of Soviet research from 1975 to 1987 is provided by Akhmetov et al [10]. Stanaway et al [11] conducted a viscous vortex ring numerical study using a spectral method to characterize this type of gas flow. Other Army studies [12–14] looked into the delivery of agents such as tear gas using vortex rings, and Navy research [15,16] aimed at generating vortex rings with gas combustion and focusing on down-range targets.

No literature was found showing successful fielding of any weapon system based on vortex research. In 1996, Dr. Andrew Wortman of ISTAR, Inc., proposed to construct a nonlethal weapon—namely, a vortex ring generator—for crowd control. The goals were to knock down a human target using repeated impacts by vortex rings and to apply dispersal agents such as tear gas. The proposal differed from the published literature in that propane and gasoline were to initiate vortex rings rather than military explosives. Figure 1 is an artist's image of a low-cost, man-portable system.

This concept was not pursued by ARL, largely because it required fielding of an entirely new system, and the trend in the Army was to reduce weight and logistics costs. ARL instead elected to develop a kit that could be retrofitted to an existing weapon system and thereby enhance performance by enabling quick conversions between lethal and nonlethal modes of crowd control.

ARL proposed a kit for the MK19-3 automatic 40-mm grenade launcher, and the U.S. Army Armament Research Development and Engineering

Center (ARDEC) initiated a program in May 1997 under the sponsorship of the U.S. Marine Corps Joint Nonlethal Weapons Directorate. The goals are to conduct a proof-of-principle demonstration for the Training and Doctrine Command in FY98 and to transition the program from ARL technology base research to PM Small Arms engineering development in FY00.

This paper outlines the technology gaps as perceived by the authors and proposes approaches for resolution. The program is not sufficiently mature to document the results of studies. The objectives of the paper are to outline the proposed program so that other organizations in government, industry, and academe that have active programs may consider coordinating with ARL to leverage resources and avoid duplication of effort.

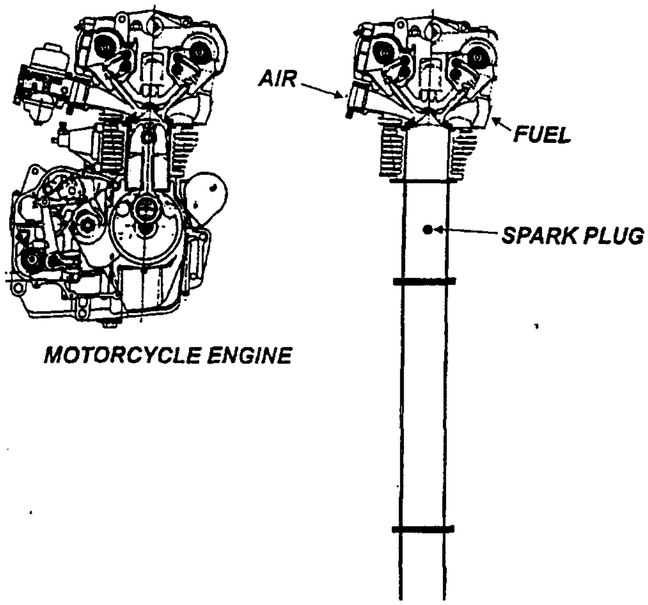

Figure 1. Conceptual variable-speed vortex ring generator.

Technical Background

Two situations of crowd control were considered at the onset of the vortex ring generator program. One was a small group of people positioned at knife-throwing distances, such as in a civilian prison riot, and the suggestion was that the 40-mm MM1 revolver grenade launcher, shown in figure 2, could be modified for nonlethal operations in these close quarters. The other situation considered was a large rioting crowd, threatening troops at a stone-throwing distance. The vision here was that a mobile, truck-mounted MK19-3 automatic 40-mm grenade launcher, shown in figure 3, could be modified for nonlethal crowd control in open areas. Only the large crowd situation is addressed here, but the technology is easily extended to the small group situation.

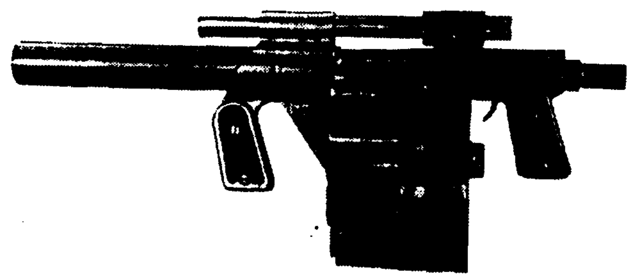

Figure 2. 40-mm MM1 revolver grenade launcher.

The concepts presented here are based on first-hand experiences with large riots in the Middle East, which left a sense of "thermoclines" in the crowd; i.e., the first few rows of people were "hot" and dangerous, and the back rows were "cooler" adventurers, who only become dangerous if mishandled. In the past, the entire crowd would be attacked with tear gas, clubs, dogs, or horses, and the result was often a larger crowd recongregating somewhere else. The modern approach uses stand-off techniques such as rubber bullets applied to individual leaders, but this is not always nonlethal and tends to incite the rioters. This paper examines the concept of crowd control using a vortex ring generator that is designed to target individuals, persuade them to

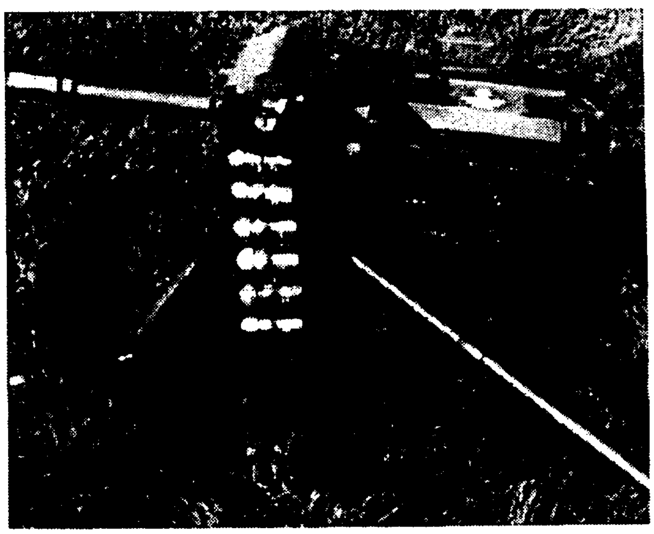

Figure 3. 40-mm MK19-3 automatic grenade launcher.

vacate the area, and promote a divorce from the main body without reprisals on the gun crew.

The vortex ring generator is a recently proposed concept for integrating several nonlethal technologies into a single weapon system. One design goal is to apply to the targeted individual a series of flash, impact, and concussion pulses at frequencies near the resonance of human body parts. Another design goal is to apply malodorous agents and marker dyes. The reasoning is that application of a malodor such as cortyl mercapton (skunk perfume) to a specific individual will cause the crowd to voluntarily pull away from that individual. And, if an individual is subjected to a chain of impulses that cause physiological discomfort, the individual will vacate the area. The net result is a break in leadership and communication without reprisals (few people have been known to return for revenge on a skunk).

ARL intends to extend the capabilities of the standard issue MK19-3 automatic 40-mm grenade launcher by designing a kit that can be retrofitted to the weapon and thereby enable quick conversions between lethal and nonlethal modes of operation. The kit consists of two components, a link of blank cartridges and a cylindrical rod. The rod houses a supersonic nozzle and reservoirs for marker and malodorous materials. The rod is mounted by sliding down the barrel until affixed to the flash arrestor. No special tooling is required, and one can quickly return the launcher to a lethal mode by pulling the rod out by hand and loading a link of live ammunition. The rod is designed to prevent accidental firing of lethal ammunition and is to be discarded after use.

Component Design Consideration

Figure 4 is an artist's view of the blank cartridge, nozzle, and barrel assembly. The blank cartridge is being developed at ARDEC, and ongoing patent processing inhibits disclosures at this time. Basic design requirements are proper chambering during automatic fire, seamless interfacing at the nozzle, and obstructed chambering of a live round to preclude accidental lethal firings. The principle of operation is for automatic firing of blank cartridges to generate high-pressure pulses of gas that are expanded by the nozzle to atmospheric pressure and to high mach number jet streams, whereupon a string of agent-laden vortex rings propagates down range, as shown in figure 5.

The nozzle must be designed to drastically reduce or eliminate the standing shock, turbulence, and burning that occurs in the conventional muzzle blast shown in figure 6. The detrimental effect of the standing shock (mach disk) on vortex propagation is apparent in figure 7, where a well-formed vortex ring unable to jump the standing shock wave is being consumed by the muzzle blast.

The ideal muzzle blast for forming and propagating a vortex ring is a short-duration "fire-hose" type of jet stream with a small expansion angle, as shown in figure 8. ARL researchers captured the image in figure 9, which shows a low-energy, 40-mm vortex ring formed in these conditions. The postulated mechanisms are that boundary layer spill-over from the nozzle causes the core to form, spin-induced entrainment of ambient air causes the core to grow, and muzzle blast convection helps the core to propagate. In this method of formation, the core of a vortex does not have to be located in space in order to inject an agent; agents are simply injected into the nozzle boundary layer. The disadvantage is inefficiency: only a fraction of the jet stream energy is transferred to the vortex and, consequently, range and effectiveness at the target are not optimal.

ARL is conducting an analytical/semi-empirical research program aimed at identifying the parameters critical to optimization of the vortex ring and to derive

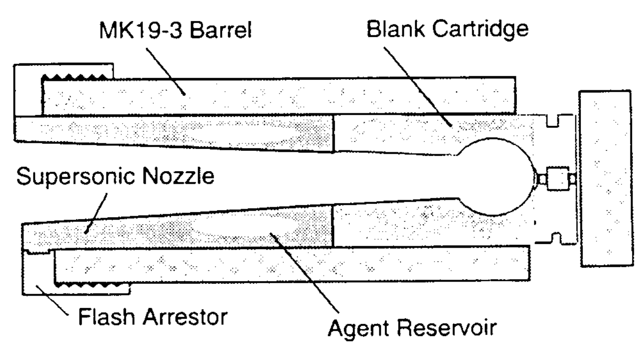

Figure 4. Artist's view of rod and cartridge assembled into gun barrel.

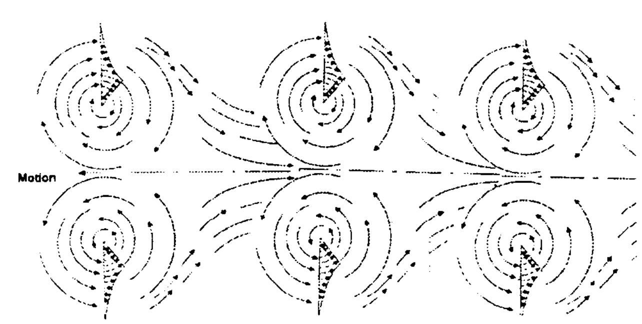

Figure 5. Series of agent-laden vortex rings propagated by automatic fire.

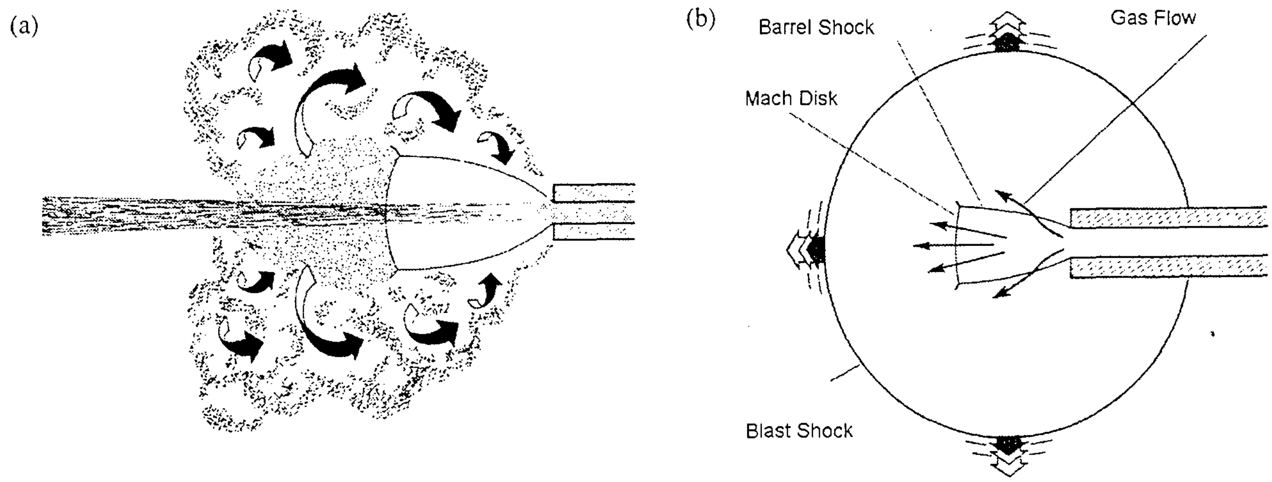

Figure 6. Illustration of muzzle blast showing (a) turbulence, burning, and shocks; and (b) traveling blast shock wave and stationary mach disk.

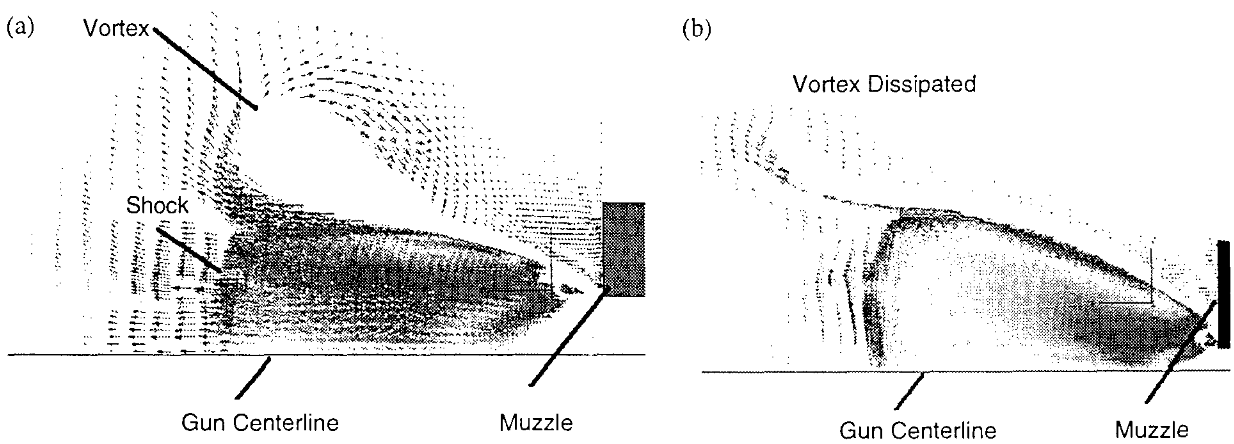

Figure 7. Half view of vortex ring: (a) expanding over normal shock (courtesy of M. Slaby, Adaptive Res., Inc.) and (b) ring consumed by the muzzle blast.

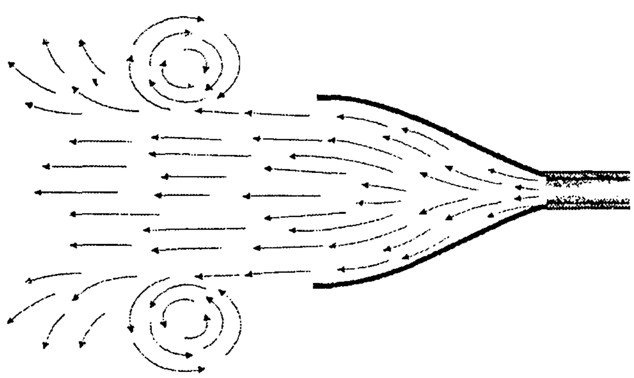

Figure 8. Laval nozzle eliminates standing shock wave (mach disk) and associated turbulence by expanding gas to atmospheric pressure.

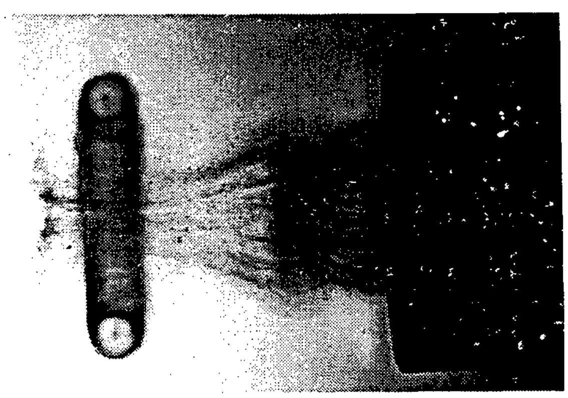

Figure 9. Low-energy, 40-mm vortex image captured by spark photography. (Courtesy of Dr. D. Lyon (ARL) and F. Dindl (ARDEC).)

scientifically based design tools for transition to development engineers at ARDEC. Computer modeling is being performed using the Adaptive Research Computational Fluid Dynamics (CFD) 2000 program and a dual-Pentium Pro personal computer. ARL plans to work in cooperation with Johns Hopkins University and to use this program in part to examine an alternate mechanism for forming a vortex—namely, to roll up the entire muzzle blast. The principle is to design the cartridge and nozzle such that the length of the gas pulse emitted from the nozzle nearly equals the diameter. The postulation is that the "spherical" shape will transform into a torroid in the fashion of the fireball in a nuclear blast. One significant advantage of this mechanism of formation is that larger quantities of agents may be transported to the target area using fewer rounds of ammunition. A possible disadvantage may be reduced range due the higher initial drag as the vortex is forming.

Regardless of the mechanism of vortex formation, the two major concerns about vortex transportation of agents are spillage and target effectiveness. Agents may spill at the gun site; in flight, agents may miss the target and strike wrong targets due to cross wind dispersal; and, agents may fail to reach the target due to wind gust shattering. We propose to resist dispersion and shattering by maximizing the angular and linear kinetic energies of the vortex using supersonic nozzles. To minimize gun site contamination, we intend to inject binary materials that must mix in flight to activate, and, to mitigate in-flight spillage from centrifugal forces, we propose to transport gaseous agents rather than aerosols.

The effectiveness of a vortex when arriving at human target is an issue for the nonlethal medical community, and guidance is needed regarding the physiological effects that may be expected from combined, low-frequency (3–15 Hz) flash, concussion, vortex, and malodorous pulses. This information is critical to the design and operation of the system. To illustrate, consider the MK19-3 in automatic fire, generating a chain of vortex rings, as shown in figure 5. The vortices will tend to leap frog and self-destruct if target effectiveness mandates vortex rings with large diameters and small separations.

Gunfire tests of nozzles and cartridges provided by ARDEC and EWS, Ltd., will be conducted at ARL, in the enclosed test chamber shown in figure 10. This facility was designed by ARL and EWS, Ltd., largely to protect the environment and staff from the acoustics and agents generated in live-fire experiments.

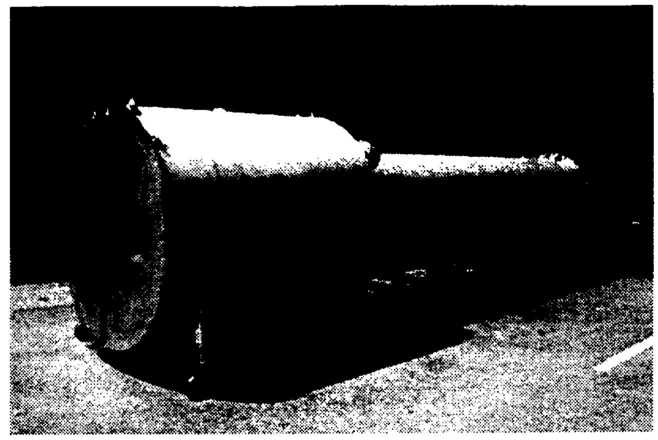

Figure 10. Confined firing chamber for vortices containing agents.

Summary

Vortex research is well documented in the published literature, but none of the studies appear to have led to fielding of a weapon system. ARL proposes to advance the state of the art by focusing on supersonic nozzles for vortex ring propagation. A fundamental technology gap is the absence of scientific design guidelines for the unsteady, nonisotropic, nonadiabatic flow that occurs when firing a blank into a nozzle. Other gaps are the absence of design guidelines for optimizing the kinetic energy and agent-carrying capacity of a vortex, transporting maximum quantities of agents, resisting dispersion and shattering in flight, and medical effects of resonating human body parts. Semi-empirical testing is required and modeling will be used to develop design tools for transition to ARDEC when a proof-of-principle demonstration of the vortex ring generator is completed. Currently, the technology gaps have been defined and approaches to resolution have been identified. A cooperative agreement has been established with ARDEC for cartridge research. An enclosed facility has been constructed for performing environmentally friendly, live-fire testing of agents. Computing hardware and software have been purchased, and prototype nozzles and cartridges are being fabricated.

Instrumentation for detecting the linear and angular kinetic energies of a vortex while still located in the muzzle blast remain undefined, and coordination of medical effects studies remain to be organized. Researchers having common interests and seeking to coordinate studies, facilities, and resources are requested to contact George Lucey by e-mail at glucey@arl.mil, by telephone at (301) 394-4342, or by fax at (301) 394-2677.

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From: John Dering (10/6/97)

Combustion Acoustics
10/6/97 4:10 PM
SARA has developed a variety of innovative and compact approaches to high energy acoustic sources. Conventional acoustic technologies are entirely unable to meet the performance requirements for non-lethal and letha acoutic weapons. These technologies were developed using the conversion of chemical/combustion energy into intense radiated sound waves. This approach has given SARA a unique technology that greatly exceeds the power requirements needed for non-lethal applications.
These technologies have made the possibility of acoustic weapons practical.
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A High-Power Electrically Driven Impulsive Acoustic Source for Target Effects Experiments and Area-Denial Applications*

H. Edwin Boesch, Jr., Bruce T. Benwell,
and Vincent J. Ellis

Army Research Laboratory
2800 Powder Mill Road
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I. Introduction and Background

A variety of acoustic sources are being developed and tested for possible application as special weapons for use in scenarios such as crowd control and area denial that call for less-than-lethal force application. These sources include devices that generate acoustic energy by repetitive combustion or detonation of a fuel-oxidizer mixture. These devices are attractive for development as fieldable weapons because they offer the advantages of simplicity of design and very high-intensity acoustic output from relatively small packages powered by common chemical fuels. The acoustic signals produced by these devices are typically repetitive impulsive waveforms similar to those generated by explosives and are characterized by an initial short-risetime, high positive sound pressure level (SPL) that falls roughly exponentially to a lower-level negative-pressure undershoot. The duration of the positive-pressure phase or pulse is typically on the order of a millisecond. In an effort to deliver significant average acoustic power and possibly excite low-frequency resonances or other nonaural response modes in a target, some of these impulsive combustion sources (ICS's) generate a train of impulses at rates on the order of 10 Hz.

Unfortunately, little is known about the effects of such repetitive ICS waveforms on potential targets at intensities of interest for less-than-lethal weapons applications. Data do exist for the physical effects of impulsive waveforms at high levels (e.g., blast overpressure effects) and for the auditory effects of such waveforms at much lower levels. However, the orders of magnitude of SPL separating these effects are largely unexplored and laboratory studies are needed. However, combustion- or detonation-driven devices are not "user-friendly" as laboratory sources, especially for indoor experimentation. In addition to the safety considerations associated with the use of fire or explosive materials, these devices can produce noxious exhaust products. They are also not well-suited to long-term systematic experimentation where ease of use and accurately repeatable performance are important considerations. As a consequence, we identified a near-term need for a user- and laboratory-friendly acoustic source that can support target effects studies and source design optimization by providing a reasonable simulation of both the waveform and SPL expected from an ICS at range on a target.

The Sequential Arc Discharge Acoustic Generator (SADAG) produces high-intensity impulsive sound waves by purely electrical means and is both user- and environment-friendly. Sound is generated in the SADAG by the sudden expansion of ionized gases produced when electrical discharges occur in air. The electrical discharges or arcs take place between electrodes in an insulating tube closed at one end and open at the other to direct the shock front (pressure wave) from the discharges to the target. The high-energy arcs are driven by electrical charge stored on high-voltage (HV) capacitors. A primary feature of the SADAG is the use of multiple arcs or discharges occurring in sequence, rather than a single arc, to generate the output acoustic waveform. This

*This work was supported in part by the U.S. Army TACOM/Armaments Research and Development Center, Picatinny Arsenal, NJ.

has two major advantages. First, the pulse width of the acoustic output may be extended and adjusted by timing the overlay of pulses from individual arcs. Second, multiple arcs are more efficient than a single arc at converting electrical energy to acoustic energy.

In operation, the prototype electrical-discharge source reliably generates impulsive waveforms at peak SPLs comparable to combustion sources at useful laboratory ranges. The source can be operated in a single-shot, repetitive, or burst mode at rates to above 20 pulses/s. The source has been employed in a critical series of target effects experiments. Further, the source technology shows promise for near-term use in facility area-denial applications.

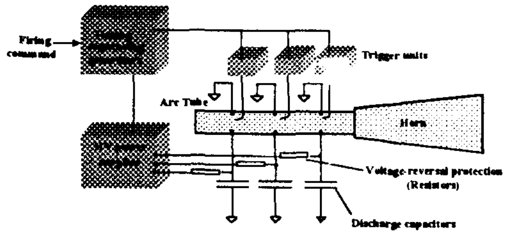


Figure 1. Block diagram of SADAG.

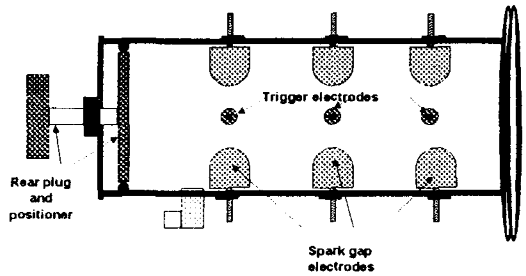


Figure 2. Detail of SADAG arc tube.

II. Description and Physics of the Device

Figure 1 is a block diagram of one embodiment of the SADAG, and figure 2 is a detail of the arc tube. In this version, three spark gaps are spaced at roughly 2-in. intervals along the length of the 2-in.-diameter, 10-in. insulating arc tube that is closed at one end with an adjustable end plate and open at the other end into a conical horn. The arc tube also includes a gas line fitting to allow the flow of nitrogen gas through the tube during operation to minimize ozone production (if required by the laboratory facility) and to provide some cooling of the tube and spark gaps for long-duration runs. The spark gaps are pairs of hemispherical electrodes mounted on opposite sides of the tube. Each gap is connected across two parallelled 2-μF, 30-kV capacitors. These capacitors are charged through series resistors by one or more high-voltage power supplies. Small trigger electrodes are also mounted on the arc tube wall at each gap, equidistant from the primary electrodes. They are connected to high-voltage trigger units that consist of automotive ignition coils and MOSFET switches. A timing/trigger generator controls source operation. This unit may be preset to cause the source to generate a single acoustic pulse upon receiving a firing command (by a manual pushbutton or electrical pulse; e.g., from a random-sequence generator) or up to 999 pulses per firing command at rates up to 20 pulses/s (burst operation). To produce each acoustic pulse, the timing circuit generates sequenced signals that activate the HV power supplies to charge the energy storage capacitors, arm the trigger units (energize the ignition coils), and then fire the trigger units in quick succession at preset intervals. When a trigger unit fires, it applies a HV transient (> 40 kV peak) to the trigger electrode located near the main spark gap. The large transient electric field in the vicinity of the sharp electrode that results causes local air breakdown (ionization) that leads quickly to air-ion avalanching and a high-current arc discharge between the main electrodes. (Discharge through the trigger electrode is limited to low currents by the inductance and resistance (resistor wire) of the ignition coil secondary circuit.)

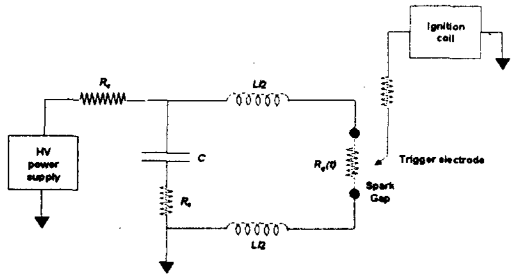


Figure 3. Equivalent circuit of one spark gap for SADAG.

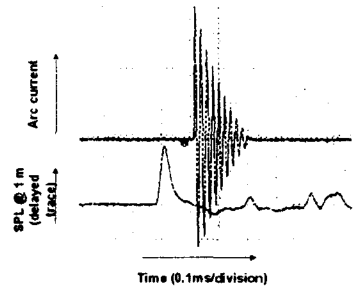


Figure 4. Upper trace: Measured current waveform for SADAG discharge. Lower trace: Acoustic pulse recorded at 1 m from source.

The equivalent circuit of a single spark gap and HV capacitor is shown in figure 3. R_c is the series charging resistance (2 kΩ), C is the HV storage capacitance, R_s is the total effective dc series resistance of C and the leads from C to the spark gap, L is the series inductance of C and the leads (assumed equal in each lead), and $R_g(t)$ is the time-dependent series resistance of the arc channel ($R_g(0) = \infty$). R_c effectively isolates the HV supply from voltage transients from the capacitor discharge circuit when the spark gap fires; therefore during the arc discharge the equivalent circuit is the simple series R-L-C consisting of $R = R_s + R_g(t)$, $L = 2\ (L/2)$, and C. Applying some freshman physics, the expected current response of this basic circuit (assuming $R_g(t)$ either constant or much smaller than R_s) is a damped sinusoid with period

$$\tau_{osc} = 1/\{1/LC - R^2/4L^2\}^{1/2} \tag{1}$$

and an envelope decay time constant for the circuit of

$$\tau_{ckt} = 2L/R\ . \tag{2}$$

Now we note that, first, the time duration of each electrical pulse is expected to be τ_{ckt} and, second, the maximum energy available to generate sound is the electrical energy dissipated in the spark gap. The latter is approximately the integral over τ_{ckt} of the power, P_{gap}, dissipated in the gap:

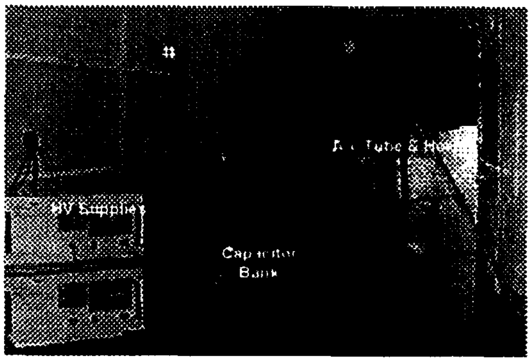
$$P_{gap} = [i(t)]^2\, R_g(t) \tag{3}$$

We want to maximize the time-averaged product in equation (3) in order to maximize the conversion of electrical energy into acoustic energy. Meanwhile, R_s should be minimized to both increase the pulse width (τ_{ckt}) and reduce the electrical power losses $[i(t)]^2 R_s$. When an electrical arc forms in air, the effective resistance of the arc is initially very high and the current is zero. As the ions multiply in the forming plasma channel, the arc resistance falls rapidly until it reaches a very low value (milliohms). Meanwhile, $i(t)$ rises, limited initially by $R_g(t)$ and then by the circuit inductance. As a result, P_{gap} is expected to reach a maximum very early (within a microsecond) after initiation of a discharge. A measured current waveform for the SADAG circuit during a discharge is shown in figure 4. For $C = 4$ µF and lead lengths to the spark gaps of about 50 cm, τ_{osc} and τ_{ckt} were about 20 and 100 µs, respectively. By remeasuring τ_{osc} and τ_{ckt} while adding series resistance and applying equations (1) and (2), we determined that the total circuit resistance, R_s, was typically about 0.05 Ω over a discharge cycle. Therefore $R_g(t)$ integrated over the discharge period must be very small, as expected. We conclude that most of the conversion of electrical energy from the discharge circuit into heated/ionized air in the spark gaps probably takes place in the early stages of the gap breakdown (in less than a microsecond) while R_g is still relatively large. As a consequence, we also conclude that a series of small discharges should be more efficient at coupling energy into the air than a single large discharge of equivalent energy. This is part of the rationale for the multiple-discharge source. In one test, the acoustic outputs from two separate spark gaps operating at 10 kV from 6-µF capacitor banks were superimposed by timing (see below); the combined peak output averaged about 16 percent (1.3 dB) greater than that of one gap operating at 10 kV from a 12-µF capacitor bank.

The use of multiple discharges also provides some flexibility for "tuning" the waveshape of the acoustic

pulse output. In normal operation of the SADAG, the rearmost spark gap is triggered first. The expanding plasma between the spark gap electrodes generates a roughly spherical expanding shock wave in the air. The position of the end plate at the rear of the arc tube can be adjusted to reflect the rearward-traveling portion of the shock wave toward the front to reinforce the trailing edge of the forward-moving portion of the pressure pulse. The firing of the second and third gaps can also be timed to either reinforce the peak of the pressure pulse from the first gap or to extend the duration of that pulse.

The version of SADAG shown in figure 5 uses a conical (linear taper) horn to more efficiently couple the pressure pulses generated in the arc tube to the air and to improve directivity.



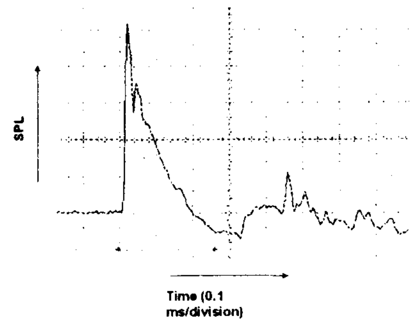


Figure 5. SADAG in position for target effects experiment. Figure 6. Waveform of a SADAG pulse (see text).

III. Performance of the Device

Figure 5 shows the SADAG configured for a laboratory effects experiment. For this experiment, two HV power supplies (shown on the left of the figure) were operated in parallel to provide rapid capacitor charging and support source operation at 12 kV or higher at pulse repetition rates to 20 Hz. The capacitors, charging resistors, and trigger circuitry were contained in the box; the arc tube and horn were mounted on the tripod. The source control circuitry (arming and firing box, trigger pulse generator) was located outside the test cell and was connected to, but electrically isolated from, the power supplies and trigger circuitry by fiber optic links. In the configuration shown, the conical horn yielded about 10 dB gain in peak SPL on-axis with respect to the arc tube alone, and the SADAG produced a reasonably uniform acoustic field (-3 dB at edges) over a 1-m diameter circle at a range of 1 m. Figure 6 shows a typical waveform of a single acoustic impulse produced by the source as measured with a precision microphone at 1 m on-axis from the mouth of the horn. The source was operated with three spark gaps and the timing of the three discharges was adjusted to maximize the recorded peak positive SPL. For this case, the capacitor charging voltage was 10 kV and the measured peak SPL was 2760 Pa, or 163 dB; the positive pulse width measured at the baseline (to first zero crossing) was 0.20 μs. . The source was operated in single pulse mode and in bursts of up to 200 pulses at rates from 5 to 20 pulses/s and (at the higher voltages, at reduced pulse repetition rates) with charging voltages from 8 to 15 kV. Over this range, the peak SPL varied from approximately 162 to 165 dB. IV. Vortex Formation

In the course of characterizing the performance of the SADAG, we found that with the proper choice of output tube it can reliably and repeatably produce toroidal vortices along with its acoustic output. Figure 7 shows plots of SPL as a function of time (2 ms/division) for an array of four microphones spaced 0.5 in. apart along a vertical line perpendicular to the axis of the source and at a range of 0.5 m from the mouth of the bare arc tube (no horn). The short positive pulse near the start of the traces is the acoustic signal with a peak SPL of about 3000 Pa (164 dB); the ~1.5-ms negative signal with an SPL near 10 kPa (174 dB) that appears 10 ms later is the signature of a vortex. The arrival time indicates a vortex linear velocity of about 50 m/s. By "scanning" the microphone array across the source axis and repeatedly firing the source, a pressure profile of the vortex was

developed (fig. 8a). At 0.5 m, the vortex toroid has an apparent diameter of about 2 1/2 in.--just slightly larger than the diameter of the arc tube. A likely cross section for the vortex is shown in figure 8b. The ease of use and accurate output repeatability of the SADAG may make it useful as a research tool to support the development of "vortex guns" for nonlethal applications.

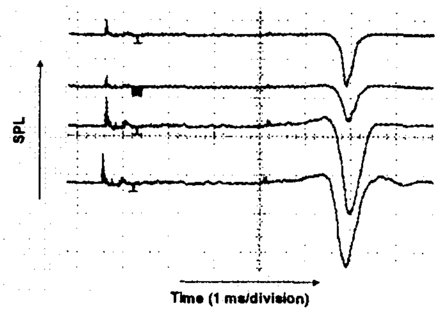


Figure 7. SPL as a function of time measured with four sensors at 0.5 m from SADAG showing vortex signature (see text).

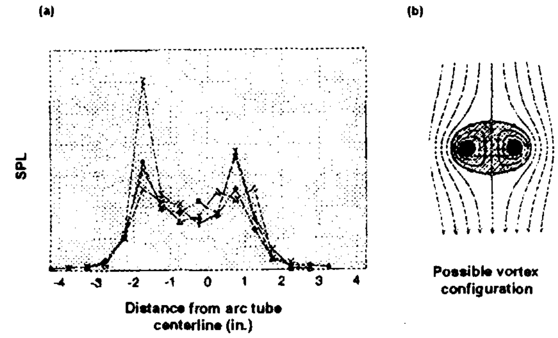


Figure 8. (a) Peak negative SPL measured as a function of sensor position in plane perpendicular to SADAG axis using repeated SADAG pulses. (b) Possible cross section of toroidal vortex that may be inferred from data in (a).

V. Future Work

The SADAG is undergoing continuous development to upgrade its acoustic power output, waveform, and general usefulness to the nonlethal program as a repetitive ICS simulator. Currently, we are placing emphasis on increasing pulse width to better simulate the output of larger detonative sources. We are also examining the extension of this technology to fixed, indoor area-denial nonlethal weapons applications.

VI. Conclusions

In under six months, we developed an all-electrical high-power acoustic source that has found application as a laboratory simulator for potentially fieldable combustion- or detonation-driven nonlethal acoustic weapons. In laboratory environments, the device reliably produces impulsive waveforms and acoustic power levels similar to those expected from the larger developmental devices. The use of multiple electrical discharges both increases the efficiency and acoustic power output of the device and allows some flexibility for adjusting the waveshape. The capability to generate the impulses at rates to 20 Hz allows investigation of the effect of repetitive impulsive waveforms on targets.

Non-Lethal Defense III

Non-Lethal Weapons

An Acoustic Blaster Demonstration Program

February, 1998

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An Acoustic Blaster Demonstration Program

Statement of the Problem

PRIMEX Physics International Company (PPI), is developing an Acoustic Blaster (patent pending) that is a credible, cost effective and simple way to employ non-lethal technology in situations in which deadly force is now an unacceptable alternative. The Acoustic Blaster is a highly and/or omni directional sound source which can be used (1) for area denial, and (2) against selected groups of crowds, intruders, mobs, and rioters in a hostile situation. Our device is compact and easily operated by one person. It can be mounted on existing platforms such as the HMMWV as shown in Figure 1.

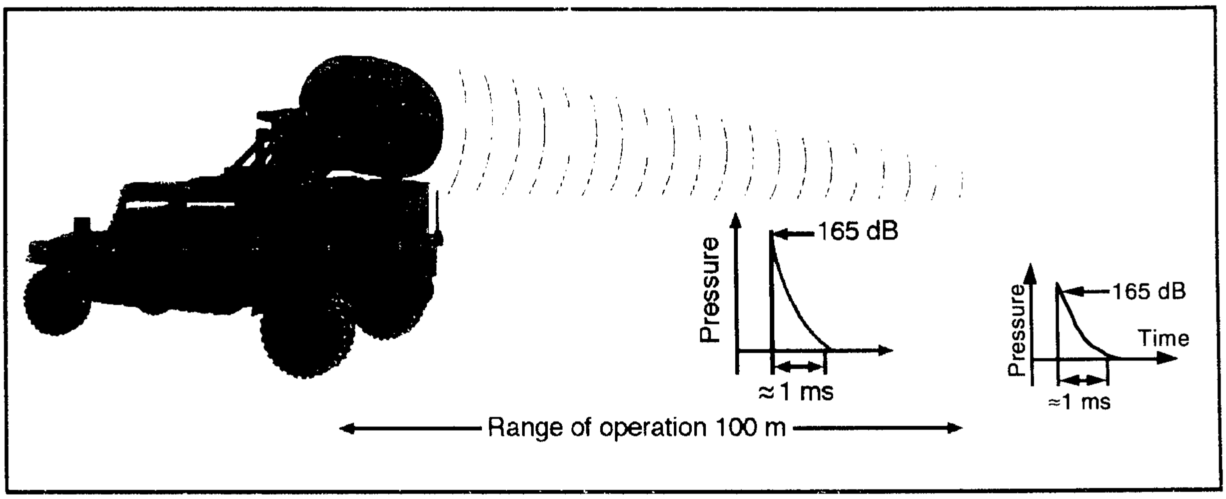

Figure 1. Acoustic Blaster Non-Lethal Device.
Deployed configuration (engineer's conceptual drawing) of the Acoustic Blaster. Blaster will provide sufficient acoustic pressure to induce pain for personnel control up to 100 m range.

An Acoustic Blaster demonstration program is currently underway at PRIMEX Physics International. A prototype blaster, consisting of an array of four (4) combustion detonation-driven devices has been developed and tested successfully (Figure 2). The prototype containing the four acoustic devices are capable of being fired simultaneously or independently. The most encouraging result thus far, is that acoustic pressure up to 165 dB at 50 ft. from the source has already been achieved. Equally important is that the output pressure waveform of the prototype blaster shown in Figure 3, appears to contain very desirable risetime and pulsewidth characteristics that are essential for optimal acoustic-physiological coupling to targets for anti-personnel applications.

Technical Approach

The key element of the Acoustic Blaster is a planar array of multiple acoustic pulsed sources, each of which is capable of independent operation and each of which generates an independent primary pressure pulse. Figure 4 is a schematic diagram of the system with an elliptic array of individual sources.

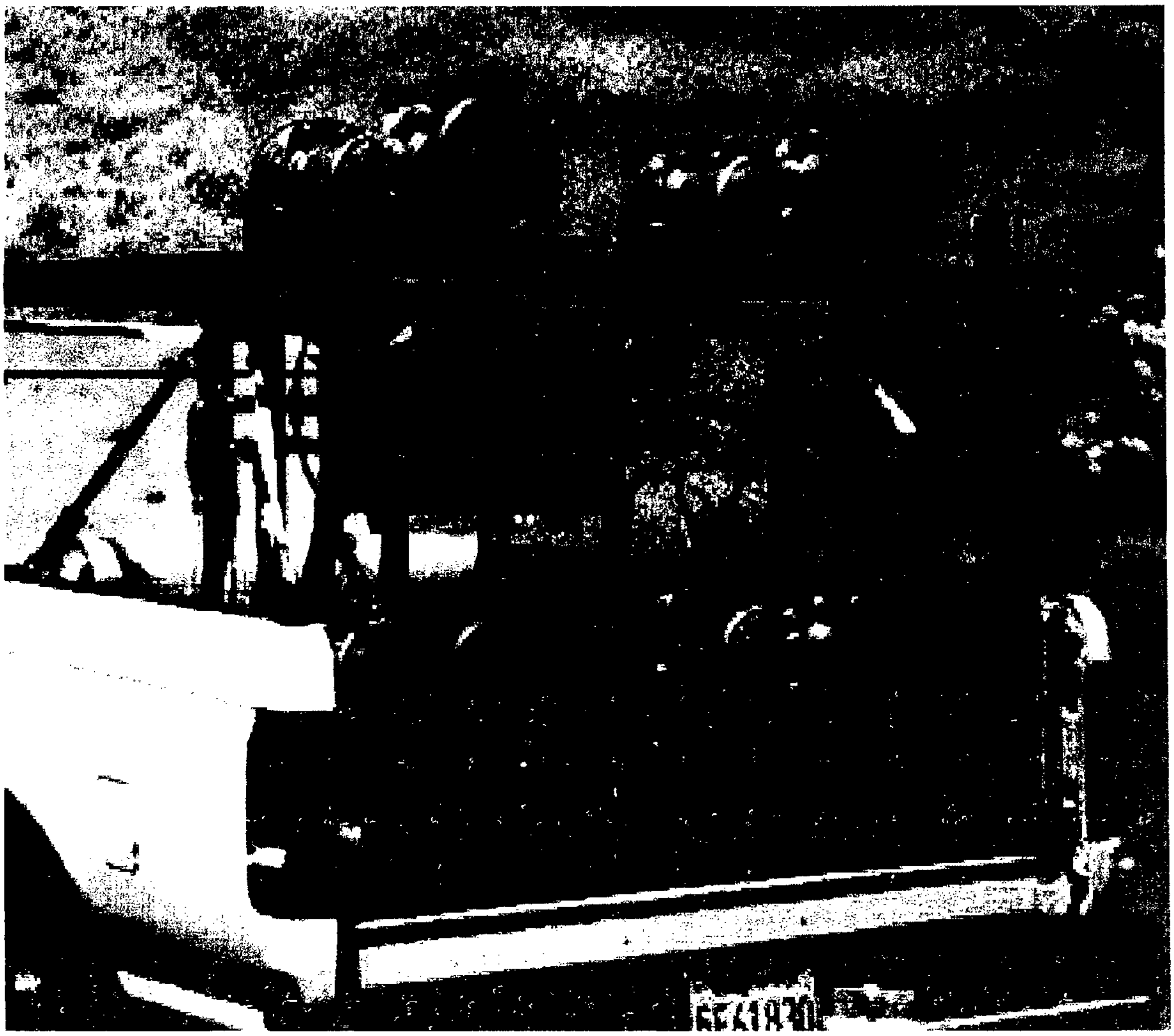

Figure 2. The Truck-Mounted PPI Acoustic Blaster.

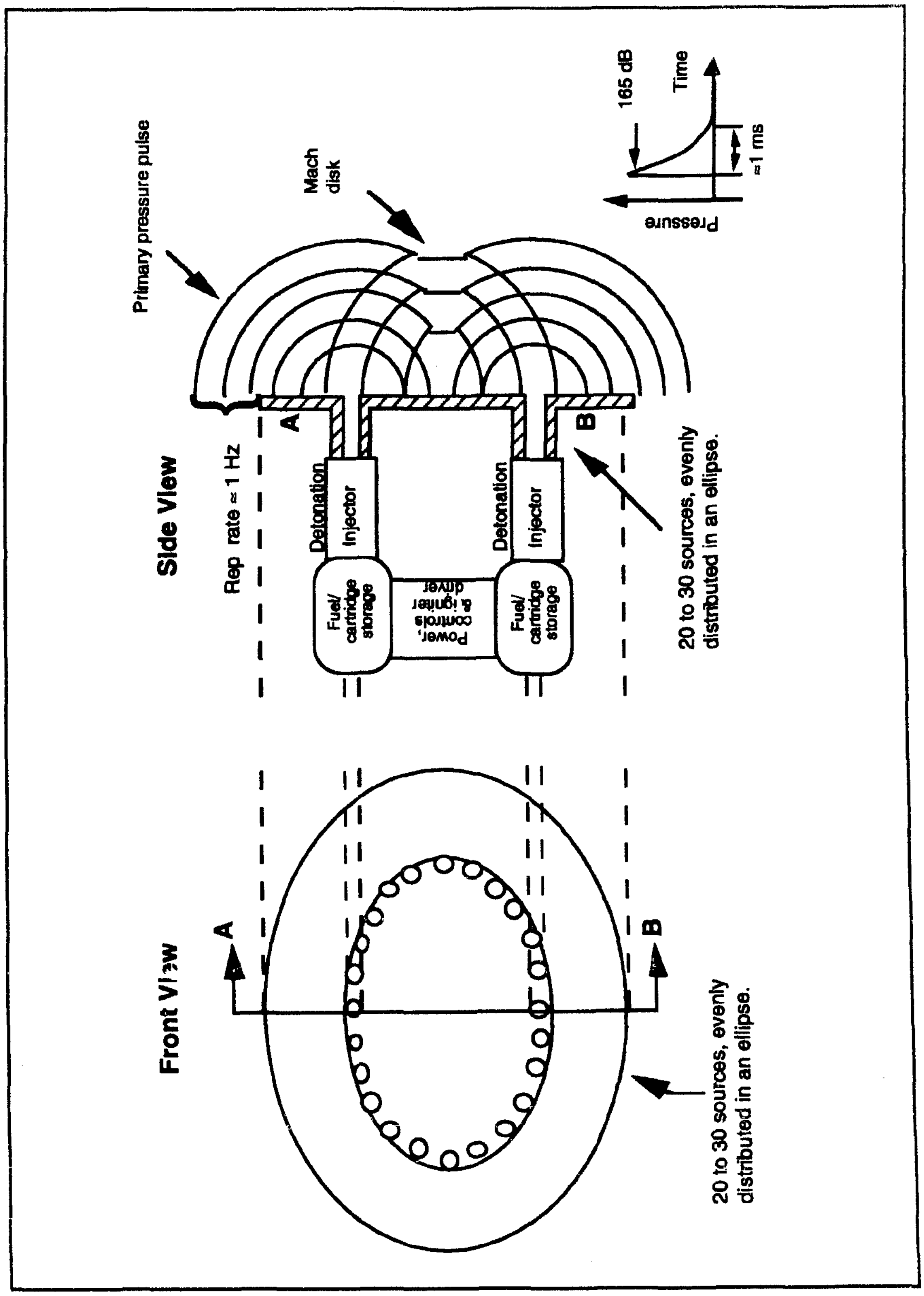

Figure 4. Acoustic Cannon Planar Array Detail - Front and Side Views.
(Sample energetic materials: detonation-driven sources or explosive charges.)

Figure 5 shows the pressure levels generated on the centerline by the proposed Blaster at ranges up to one kilometer for various masses of energetic material (in equivalent mass of TNT) expended in the entire array. We generate the data in this figure using results from a linear analysis which provides a conservative lower bound on the pressure magnitudes. Due to the unique phased array effect of the addition of the individual pulses along the center line, the linear pressure in the combined pulse is $n^{2/3}$ times the pressure of a pulse generated by one single source with equal amount of energetic material. This gain is analogous to the power density gain of a phased array of microwave antennas. The indicated pressure levels cause disorientation and debilitation at ranges of 100 to 200 m. All levels are less than lethal.

Threshold of pain (CW)
- Infrasound (50-100 Hz): 145 dB *(subjectively intolerable)*
- Human hearing range: 150 dB
- Airborne ultrasound: heating effects (long exposures) @>175 dB

Rupture of human tympanic membrane
(age and individual dependent)
- Minimum: 185 dB (5-6 psi)
- Average: 195 dB (23 psi)

Pulmonary injury (3 ms. pulse)
- Onset: 200 dB (30 psi)
- Lethality: 220 dB (100 psi)

Impulse force (2 mph jolt)
- Diffraction phase: 90 psi
- Drag phase: depends upon duration (many ms. required)

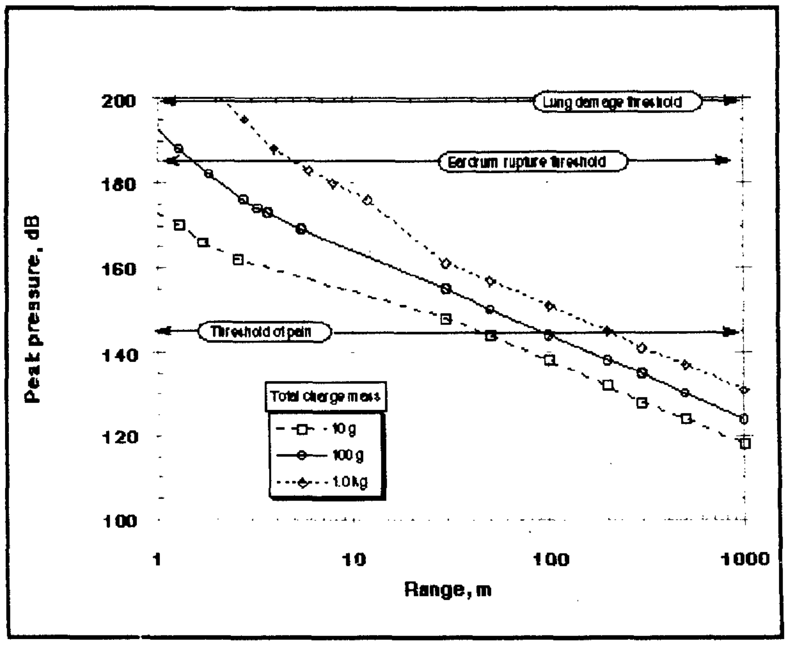

Figure 5. Physiological Effects of Intense Sound.

Preliminary **non-linear** analyses show that there are three major advantages to using "n" multiple individual pulses rather than one strong pulse. First, the formation of a non-linear shock wave (Mach disk or acoustic soliton) will likely lead to significant intensity enhancement. The radial extent of the Mach disk is limited, which allows the system to focus the high intensity pulse over a small area at ranges of order 100 m. Second, the intensity in the mach disk falls off more slowly with distance than the inverse-range-squared behavior of a single, spherically expanding pulse. Third, the temporal width in the Mach disk (sketch in the lower right corner of Figure 4) is the same as that in the individual pulses. Since the width of a pulse increases as the

one-third power of its initial energy, the composite pulse delivers its energy in a shorter time (higher power, therefore, higher peak pressure) compared to a monolithic pulse with the same initial energy.

An initial review of the literature on the biologic effects of high intensity sound indicates that the magnitude of these effects depends not only on the peak pressure but also on the pulse risetime, the pulse width and the pulse repetition frequency.

The risetime of pressure is a threshold effect – all pulses with a risetime short compared to the transit time over the target will have the same desired effect. This time is approximately 100 μs, which is long compared to the pressure risetime in a strong shock wave.

Pulse width requirements for maximum effect vary but are generally on the order of one msec. This requirement is well matched to the propagation and evolution of intense sound waves. Frequencies below 2000 Hz disperse rapidly from the sources. On the other hand, frequencies above 5000 Hz are rapidly attenuated by molecular dissipation. The duration of the positive pressure phase of the pulse, which may be critical to effects coupling, becomes stable at distances beyond 10 m.

The pulse width depends on the energy release in the acoustic elements and is controlled through the amount of energetic material, its composition (i.e., burn rate) and its geometry. Since peak pressure at a given range depends on the initial amount of material used, simultaneous cont- ` oi pulse width and magnitude involves varying both the amount of material and the number of source elements per shot.

The effects literature suggests that the biologic effects are sensitive to the pulse repetition rates. We estimate this rate to lie between one-fifth and one Hz. However, we do not consider this to be a critical design parameter because it is possible to operate the system at rates up to several Hz.

Initial system configuration analyses have identified several possible candidates for the energetic acoustic source material. Five examples are: 1) a pulsed detonation device or

advanced shock tube which produces extremely high pressure in small volumes; 2) a pumped liquid, such as liquid propane, mixed with high pressure air; 3) a liquid bi-propellant such as hydroxyl; 4) a fast burning solid material, such as pistol powder, in a combustible cartridge; and 5) noisy spark-gaps which allow an all-electric system configuration. All five technologies are "clean" in the sense that no residue or waste material remains at the site of operation. Trade studies will consider the advantages and disadvantages of each approach.

To summarize, we have reached our first milestone to develop and test a prototype Acoustic Blaster for non-lethal area denial and/or crowd control applications. We are poised to begin an engineering optimization and product implementation program to provide a credible, cost effective and simple acoustic device for many non-lethal military and law enforcement applications.

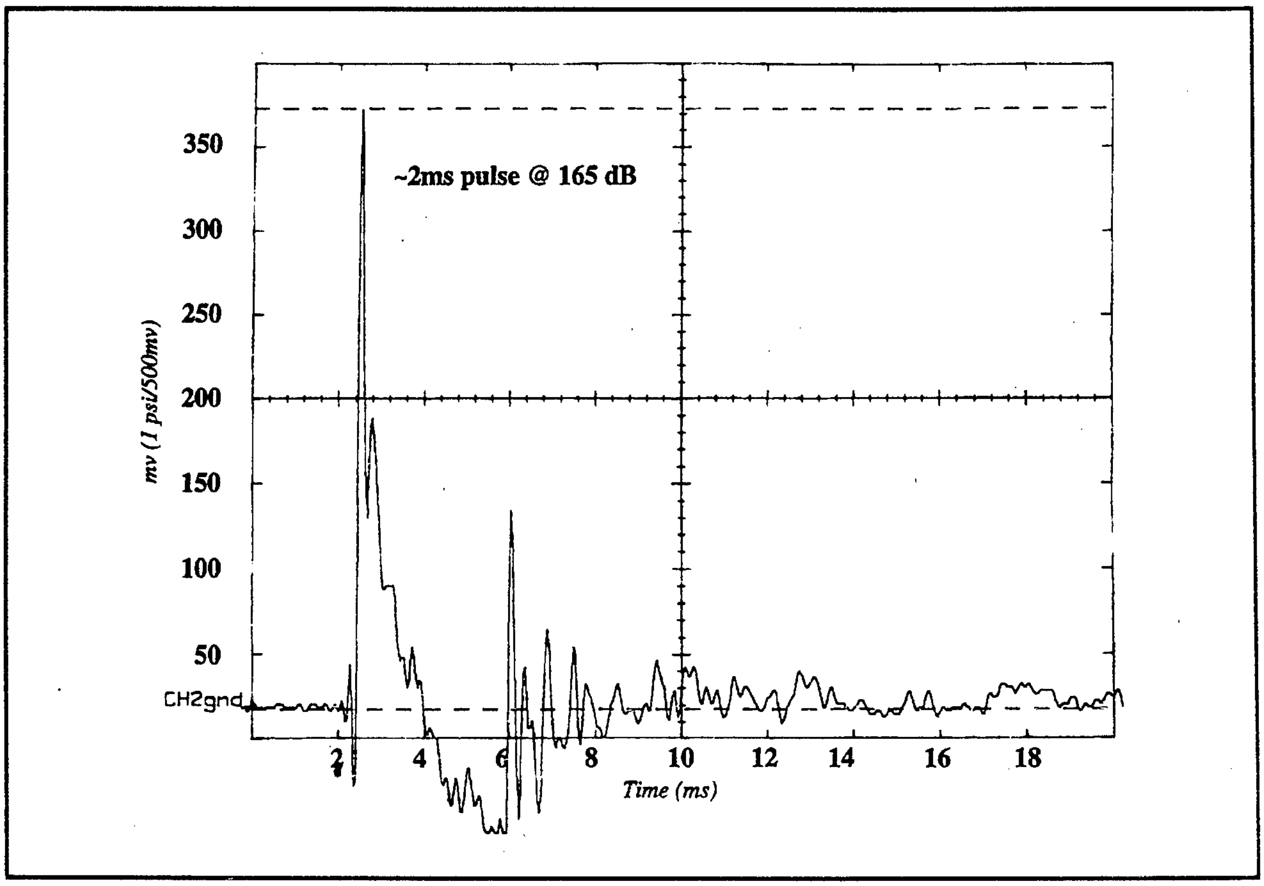

Figure 3. Acoustic Pulse Shape.
Time vs. Acoustic Pressure @ 50 ft. from source.

Non-Lethal Defense III

Dual Use Technology: An Implementation Plan

Non-Lethal Technology
for our Era and Culture

by

Matt Begert and Duane Preimsberger

Dual Use Technologies: An Implementation Plan

To the policemen in the midst of an altercation between the 18th Street Gang and the Bloods, and to a soldier positioned between an angry Croat and Serbian mob, the situation at hand looks very, very similar. And, significantly, in both scenarios, the need for technology to deal with that dilemma exceeds the technology available.

The mob scene is very different from the force-on-force scenario that the US has built and maintained to oppose the Soviet Union. Several scholars suggest that "winning" the Cold War was a result of America's technological edge. But now we are getting indicators that the technology is focused on the wrong type of conflict and war.

Winning the Cold War and dominating the battlefield in the Persian Gulf war established the US as a premier force in a general war where tanks, ships and planes dominate the landscape. But its becoming evident that the battlefield landscape is changing and that general war force, and the technology supporting it, doesn't do well on the new playing field. This playing field is starting to look muddy.

"We can expect those opposed to our interest to confront us at home and abroad—possibly in both places at once—with asymmetrical responses to our traditional strengths."[i]

Translated, that means that no opponent, be he criminal, terrorist or thug is likely to let the US fight its type of engagement.

"The idea that some sandlocked strongman is going to jerk Uncle Sam's beard and then invite him to a rematch at Desert Storm—do you believe that is going to happen? Who would do that?" said General Krulak, Commandant of the Marine Corps, in concurrence with the Defense Panel's view.[ii]

So in a nutshell, an asymmetrical threat means that the bad guys aren't going to want to fight the way we do. More than likely, they won't play by our rules and they won't play fair. And that may mean that the way of fighting and the focus of technology are off in the wrong direction. We may need to get both on a different track, and very quickly.

In the fall of 1993, US Army Rangers were faced with the difficult mission of capturing Somali militia leader Mohamed Farah Aideed hiding in the crowded city of Mogadishu.

"We're not cops and we're having to adopt war-fighting technology for a fugitive hunt in a city of about a million," said one US officer.[iii]

Another US official described the situation this way: "We played by our rules and he doesn't play by our rules. He surrounds himself with women and children and stays in the most crowded part of the city. So by setting these rules we limited the effectiveness of our force."[iv]

Two parts of this puzzle deserve attention. On the one hand, estimating the situation and the opponent and on the other, bringing the technology to bear, effectively, on that opponent. But who is the opponent, how does he fight, and why?

Back to the introductory dilemma for the answer. There are only two differences: Police man and soldier as operators; domestic versus foreign geography. Both our operators face a situation where a continuum of force is more effective than the choice between "doing nothing" and lethal force. Both operate in an urban environment with a benign populace mingling and muddying the "battlefield." Though the motivations of the mobs may be different, to our first responders, the situations, and the necessary responses are not different. . But both could use effective non-lethal technology immediately.

This looks a lot like what this nation's law enforcement and corrections officers deal with daily. But what are the similarities and differences?

Our domestic law enforcement (LE) exists with permanency. Military missions of peacekeeping and presence are designed to be temporary. The end-state of LE is the maintenance and/or restoration of order. The military mission end-state is either end (of mission), change (of mission) or departure (including departure under pressure). It involves ingress, time to establish authority and a posturing to hand off the maintenance of order to a legitimate political authority. Presently, this military mission involves commitment of forces to external citizens/nations for a stated US national interest. However, if predictions for the need for "homeland defense" are accurate, that may change.[v] Certainly the creation of the USMC ChemBio Incident Response Force and the DOD terrorism training for major US cities is an indicator that we are acknowledging that threat.

Crime in our country, because of its potential threat, is more personal than a CNN report of atrocities outside our borders. Yet the "political" motivation of actions by a Saddam Hussein are arguably similar to the felony evil of a drug dealer or domestic terrorist. The difference may be no more than the geography.

The tribulation of a peace officer chasing a criminal across city, county or state political boundaries may be frustrating, but long term cooperation of the involved agencies lessen this obstacle. In the military mission of peacekeeping/presence, that cooperation is non-existant or tenuous at best.

Success of the military mission is often opposed by a non-state soldier (no uniform, not bound by Rules of Engagement and able to blend into the populace). LE calls him a criminal. But terrorism as war and terrorism as a crime have the same consequences. To the first responder, whether a soldier or police officer, the cause is less an issue than the consequence. The consequences look remarkably similar.

In this murky world where the FLOT (forward line of troops) can't be drawn on a map, where soldiers don't look like soldiers, and where political commitment looks a lot like hate, greed, revenge and felony evil, the right non-lethal technology could go a long way in helping to shape and control this "battlefield" where restraint, behavior modification and the destruction of relationships and bonds is more important than killing.

Looking a little closer at these emerging military missions, we can see more similarities to the challenges of LE. The environment is urban and the mission is difficult to define. The goal of the strategy is to "not lose" rather than win. Conflict is intrastate and there is no conventional enemy. Opposing leaders are charismatic rather than authoritarian, which may make the opposing

"force" more unpredictable. The objective is indefinable/undetectable and the opponent actions may be as much spontaneous as planned. Restraint is more important than boldness.

In his introduction to "The Small Wars Manual of the United States Marine Corps of 1940," Ronald Schaffer points out that what was considered a "small war" in 1940 is quite similar to the peacekeeping mission of today.

"The Marines' own psychology would have to be different from that of regular wars. In a conventional conflict, one aroused courage in troops by instilling hatred of the enemy. In a small wars, it would be necessary to be ruthless and firm at times; yet the Marines would be dealing with the native population as well as the enemy (though the distinction between the two would not always be clear) and their relations with the people had to be tolerant, sympathetic and kind."[vi]

Operations in this environment are manpower intensive, are very personal, require constant situational assessment are bound by rigid rules of engagement/force policies and lack a conventional hierarchical command and control architecture. The situation requires a higher intensity of training of the individual soldier or policeman. Tactical pull rather than strategic push drives the never-ending operation. CNN's presence and opinion affect both environments.

So should we not apply our technical expertise to this differing style of conflict? If a strong technical edge helped in the Cold War struggle, it should not be difficult to do once we fully recognize that the problem is different.

The race to build a capability to technically support a system integration of non-lethal weapons and tools will be interesting and challenging. Yet the potential synergy of DOD lab and research capability, the search for equipment of military utility and the practical, hands-on feedback contribution of LE has great potential. The challenge is to connect the dots between the LE base of experience, military operational needs and the technology focus.

The present orientation of Department of Defense (DOD) Research and Development (R&D) labs and Research Centers, toward force-on-force attrition warfare, cannot successfully address the challenges of non-lethal weapons development. Current weapons system programs are complicated, expensive and require years of development to complete. These programs have layers of management and administration. This structure is unsuited to a change in technology required by our new era and culture.

Yet successful examples of responsive technical organizations like the Lockheed Skunkworks have a surprisingly straightforward set of principles that endure and work, resulting in products, such as the SR-71 aircraft, that are designed and built ahead of their time. Can this style of entrepreneurial operations be applied to military labs/research centers while avoiding the ponderous over-management characteristics like many of the larger weapons programs?

Technology support might best work like this: Build a sufficiently knowledgeable technical group to address the challenges and have them review the history of the problems and the solutions of the past. The initial focus of effort should be to look at systems of the past both good and bad and examine why those unaccepted systems were rejected.

Questioning why a system was rejected is important. Henry Petroski, in his book, "The Evolution of Useful Things," explains that "...function follows failure," observing that the dissatisfaction with current tools, equipment and inventions inevitably leads to something more useful or functional.[vii]

It is essential that concepts drive the technology and not the other way around. Our sharp, innovate organization, then, is built around those concepts and the need for non-lethal weapons and tools. Organizational leaders are inventors, scientists, engineers, innovators and technicians, and their focus of effort is on identification and production of new, useful products.[viii] Cooperative effort among inventors and users is essential.

The road from concept to production and use is fraught with dangerous pitfalls that have to be avoided. As the organization matures, there will be an increased emphasis on management. That should be minimized. Micro-management is a showstopper. Involvement of operators, which in the non-lethal technology example would include law enforcement and military representatives, must be continual and frequent. The differing points of view would actually assist development.

Avoid a stack-up of negatives and encourage new ideas while at the same time avoid trying to beat life into a dead horse. If there is no chance for new ideas to grow into prototypes, there will be no continued development. Actually, just building something with promise will accelerate development, and using it reveals the human factors that are not obvious in a paper study or model/simulation.

A current example is the reexamination of the M234 riot control launcher and projectiles invented and type classified in the 1970's. It remained shelved, unused and largely unexamined until its favorable review by the US Attorney General's Report on Less-Than-Lethal Weapons of 1987.[ix] But it again remained unevolved until a resurrection of interest in 1996. The potential of this technology, with modification and next generation development, is at least now being examined and tested.

But even this example of renewed interest reveals the weakness: There has been little continuity in less-than-lethal development. There have been no maestros of technologies that have perpetuated a continual stream of corporate memory. Rather, it has been a chronology of fits and starts, with changes in services leading the programs. There has been no coordinated effort to continually evaluate kinetic energy impact devices, chemical delivery systems, acoustics, high-powered microwaves, lasers and other technologies in light of concepts and requirements.

The advantage of re-examining the M234 include its non-lethality characteristics supported by extensive biomedical testing, done at military research facilities, before it was type classified by the US Army. With this jump-start, it has the potential to lead to a next generation device or point the way to a new idea. Gene Stoner, the creator of the M-16, may well have spoken accurately when he, in 1970, described the M234 system as 20 years ahead of its time.

Every user requirement cannot be satisfied. The perfect product never comes. Select items and systems that can support the requirement, support their development, and get on with it.[x] And in the meantime, come up with new concepts; examine them and see if we can apply compatible technology. Examine ways to deliver, dispense chemicals and launch projectiles, as

examples. In doing this, we should consider dual use non-lethal technology because it fits our era and our culture. One of the attractive things of dual use is that it goes both ways: Military development to LE use and LE use to military concept and development.

Like it or not, the manner and scope of warfare is in transition and throughout time this has always been the case and those best able to deal with the changes usually came away the winner. As we look back in history we find that the major changes in warfare almost always deal with technology, not only the tools used; for example, bronze to iron, catapults to cannon and from horse cavalry to tanks. Change also included the manner of implementing the use of those tools as well as the tactics of the battlefield which today differ somewhat from those used by Hannibal or US Grant.

Today, our first responders, be they soldiers, sailors, airmen, Marines, coastguardsmen, peace officers, firemen or any combination thereof, again find themselves in a transition, at a time when both tools and tactics are changing. For many it is the best of times and the worst of times. Best, because we can face a dilemma and cause our forces to sieze the opportunity to change and do it wisely and beneficially. Worst, because change is an event feared and avoided. However, in order to come away a winner, we must step up to that need for change given our environment and the tactics of our foes.

To some, the circumstances parallel a baseball game. It's the bottom of the ninth, score is tied, two outs and a full count. As Casey Stengle would say, "Hit me a home run, it ain't time to bunt."

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[i] Anderson, Jon R, "Pushing toward a Brave New World/Experiments with Brash Names Like 'Hunter Warrior,' 'Silent Fury' and Ring of Fire' are Defining a New Era that Could Turn the Military Upside Down, Navy Times, January 5, 1998.

[ii] Ibid.

[iii] Lancaster, John, "Mission Incomplete, Rangers Pack Up Missteps, Heavy Casualties Marked Futile Hunt in Mogadishu, The Washington Post, October 21, 1993.

[iv] Ibid.

[v] National Defense Panel, "Transforming Defense, National Security in the 21st Century, December, 1997, Arlington, VA, pp28.

[vi] Schaffer, Ronald, "The 1940 Small Wars manual and the "Lessons of History," Military Affairs, April, 1972, pp 46-51.

[vii] Petroski, Henry, "The Evolution of Useful Things," Vintage Books, 1992.

[viii] Flatau, Abe, "Lecture to Advanced Ordnance Officers' School," Aberdeen Proving Grounds, Md, May, 1980.

[ix] Sweetman, Sherri, " US Attorney General's Report on Less-than-Lethal Weapons," March 1987.

[x] Watson Watt, the British inventor of radar, described it this way: "Best never comes, second best takes too long; pick the third best, the one that satisfies the requirement in the least amount of time, and get on with it." It became known as Watson Watt's Law of Third Best.

Swedish Non-Lethal Weapons Research Activities

presented by
Curt Larsson, Director of Research
and
Bengt Wigbrant, Senior Research Officer
National Defence Research Establishment in Sweden.

The Swedish Defense Research Establishment (**FOA**) is purely governmental with about 1100 research officers employed of which a third are doctors. The research work is done in different areas i.e. NBC up in the north, weapon and ammo development in the vicinity of Stockholm and IT and EW in Linkoping in the south of Sweden.

Also the NLW-program is run from Linkoping. Mr Larsssson and mr Wigbrant are occupied with that program.

Although Sweden has a long history of participating in peace-keeping contributions it took until a few years ago before it was decided that **FOA** should be of assistance in order to make the work easier for the observers and forces who were acting internationally. The program "Technic for International Contributions" was launched with Larsson and Wigbrant as managers.

The first thing that we did was to travel to a lot of places where Sweden was represented in peace-keeping. In every place we made ourselves familiar with the circumstances and spent many hours asking people what were the difficulties and risks in their job.

Very soon we found certain difficulties in common for all contingents: first of all landmines and snipers (especially in former Yugoslavia). These particular items were already taken care of by other research officers but we found many other obstacles that nobody at home had payed any attention to. Most of these obstacles could in fact be taken care of under the "umbrella" NLW. We decided to start with tryung to find solutions of three different impediments *all related to real situations described by peace-keeping personnel.*

Situation 1.

Actually this turned out to be an occasion where we were present by the happening.
We were visiting a chek-point manned by scandinavian UN-soldiers. Standing there we witnessed how a military convoy took no consideration to UN prohibition to pass the check-point. Instead the military commander used a bulldozer to destroy a barrier and move two APCs in order to clean the road, after which the convoy passed saluting the UN soldiers.
This situation has occurred many times in different places and is of course not good for the image of UN!
Anyway - here is a situation where the use of firearms could escalate a conflict. We had to try other means to stop the vehicles, preferrably using NLW.

One way to force a vehicle to stop is to disturbe or destroy the electronics that controlle the engine.Since we at FOA have a project on HPM (High Power Microwaves) we first thought of using this technique. Our experts told us that it would be possible in the next 5 years and that we then could stop a vehicle at a distance of some kilometers. But the equipment was needed now and the main thing is the very short distance of just 10 to 15 meters to the vehicle that you want to stop After some calculations we found that the power of an ordinary radartransmitter might be enough. Shown in figur 1 is an exemple of the powerdensity from two radartransmitters as a function of distance.

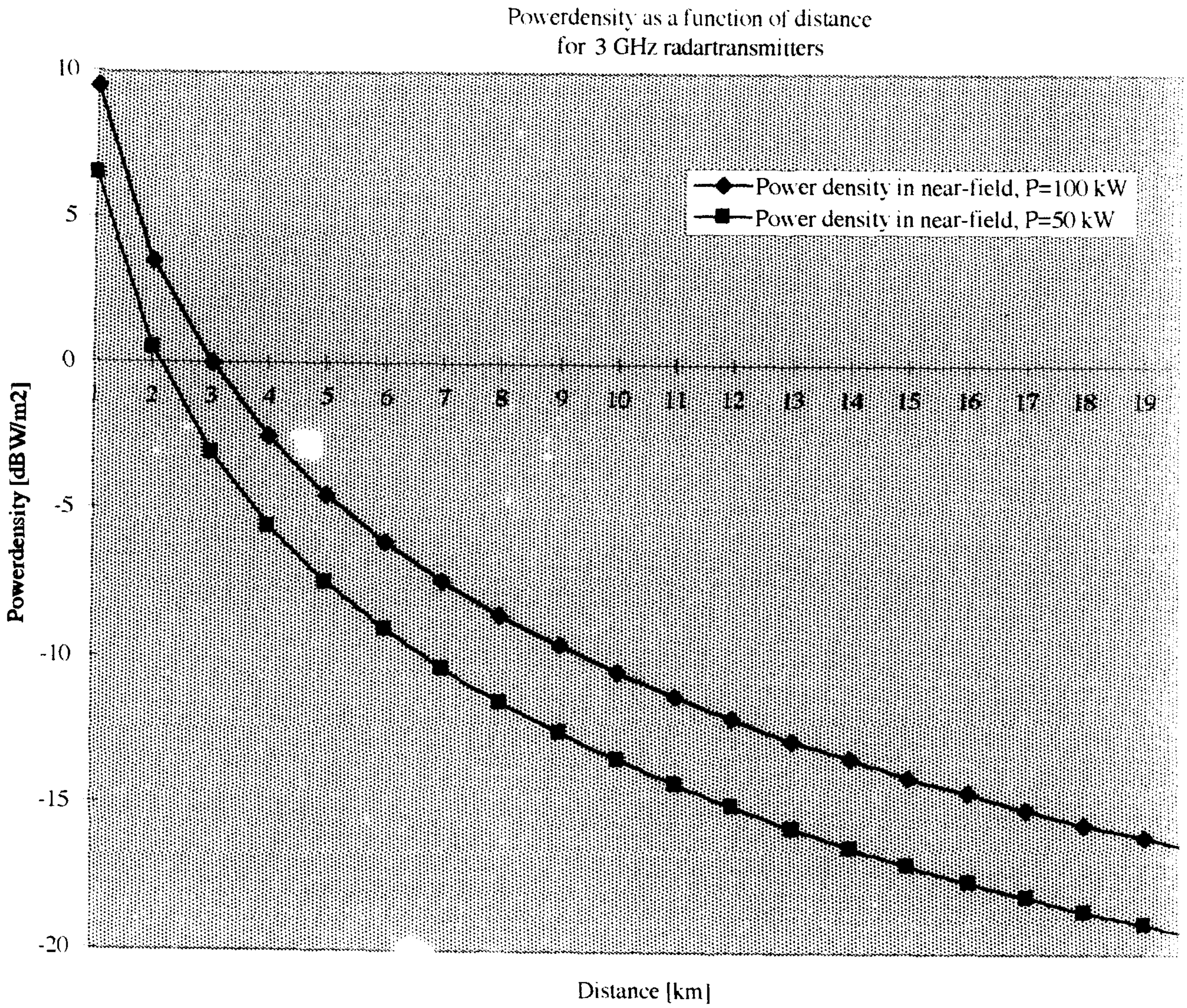

Figure 1

As seen above at normal radardistances the powerdensity is much too low to have any influence on a vehicle. But if we look at the nearfield just some meters from the antenna, see figure 2, we have a powerdensity well above the level where we can expect disturbances or even damage on engine electronics. Consequently it is possible in theory to stop a vehicle using a radar but we needed to prove it in practice.

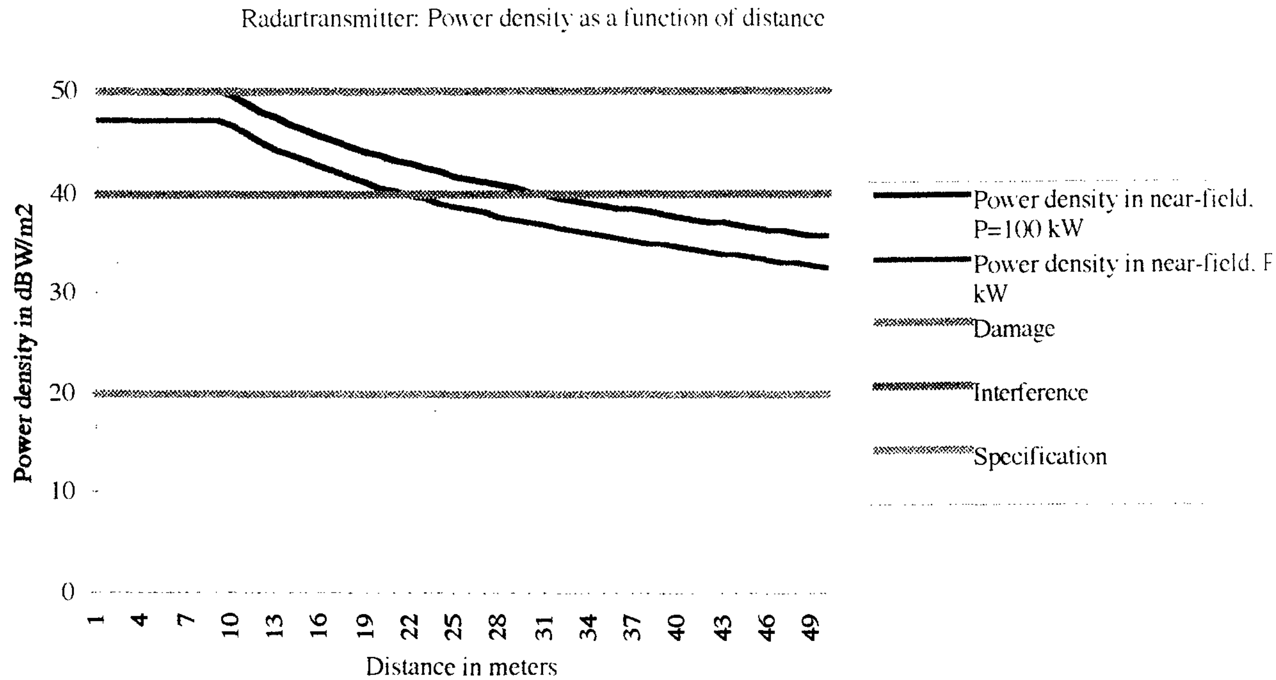

Figure 2.

The experiment was carried out in December 1995. We used a system called The Microwave Test Facility (MTF) that is capable of generating a number of radarfrequency bands at high power, see table 1.

Frequencyband	Fieldstrength V/m, max
L (1-2 GHz)	31000
S (2-4 GHz)	34000
C (4-8 GHz)	17000
X (8-12 GHz)	11000
Ku (12-18 GHz)	6100

Table 1. Given fieldstrength at 15 m distance.

The test vehicle was placed 15 meters from the transmitter antenna. Irradiation was done from two directions, see figure 3.

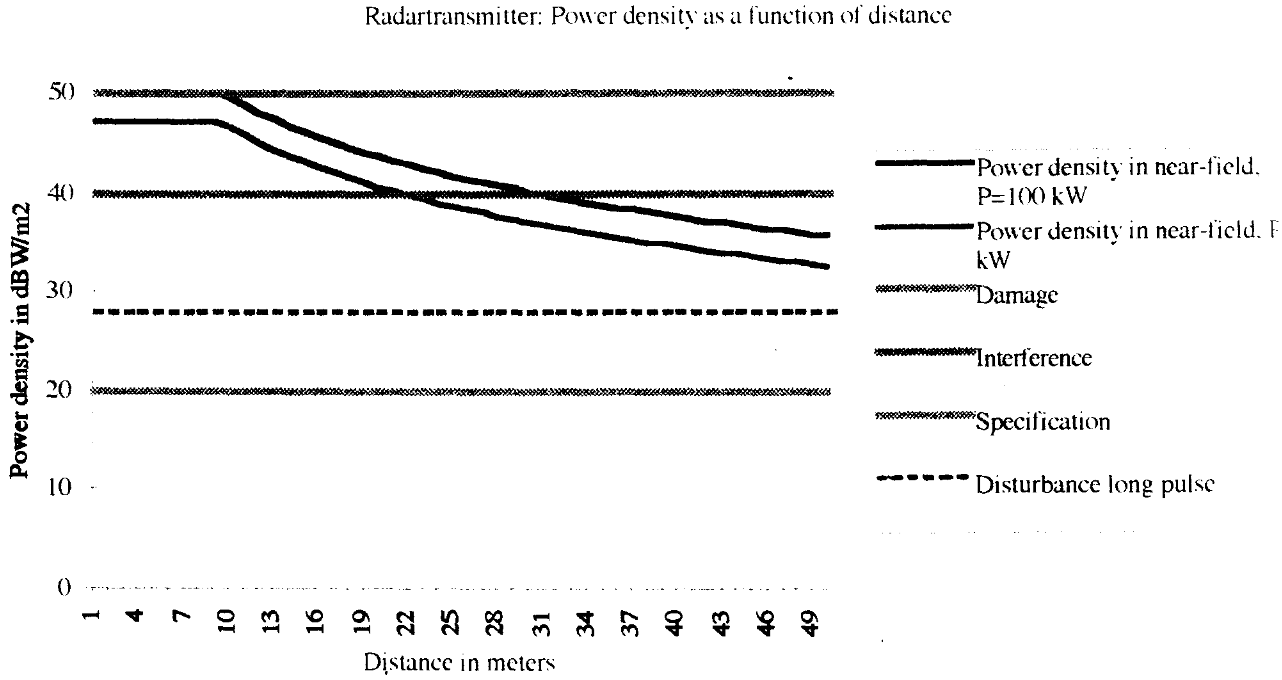

Figure 4.

Situation 2.

During the "UN-time" the swedish battalion in Bosnia had great difficulties to solve their task to escort certain transports from one village to another. What happened was that old people and children sat very passive on the road thereby blocking the UN convoy sometimes more than 70 hours. We had to find a solution where the demonstrators could be dispersed without any casualities. The solution seemed to be using acoustics.

Acoustic signals can be divided into three main types depending on the frequency response of the human ear:

• Ultra sound	> 20000 Hz
• Audible sound	16 - 20000 Hz
• Infra sound	< 16 Hz

We shall now give a short description of these three sound types and their potentials as non-lethal weapons.

Ultra sound

Ultra sound has the advantage of being easy to direct - it could be sent out as an acoustic bullet. However the signal is quickly absorbed in air and looses its energy after just a few meters. This means that a person exposed to an ultra sound bullet at close range first would feel just a tickling but as the sound source gets just a few inches closer the acoustic field increases rapidly and there is a great risk of getting a lasting burn on the skin. For this reason we don't think that ultra sound is suitable as a non-lethal weapon. In the table below the main features of ultra sound as a NLW are given.

+ easy to direct

Non-Lethal Weapons Activities at ICT

Paper presented at NDIA'S „Non-Lethal Defense III" 24-26 February 1998

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1. German Definition of Non-Lethal Weapons (Slide 1)

At first I want to inform of the German definition of NLW:

Non-Lethal Weapons are:

„Technical means whose intention is to obviate (prevent or stop) hostile operations without causing death or lasting injury to human beings.

In addition, secondary effects caused by the use of those means to innocent people, property, and environment shall be minimised".

This refers to the basic study of DASA.

2. Activities on Non-Lethal Weapons in Germany (Slide 2)

Slide 2 gives an overview about the activities. These activities started in the end of 1993 when German MOD placed an order with DASA for working out a study on NLW. It was followed by the foundation of a BWB-study group in 1995 and a presentation on NLW in the test area of the German army in Hammelburg which was organised also by BWB in 1996.

In the middle of the last year BWB placed three orders, first the development of a Ranging Gun and additional an Effector Net, second an Infra Sound Generator and third an Audible Irritating Sound Machine.

3. Activities on Non-Lethal Weapons at ICT (Slides 3 & 4)

As mentioned previously main area of working fields of ICT concern technological tasks. Based on a technological approach main competencies of ICT must be taken as a basis for a conception as to the topic of Non-Lethal Weapons.

For this the scientific and technological basis concern:

- Particle Technology
- Polymer Technology
- Gas-Generator Technology
- Combustion Technology

Developing several Project-Ideas is resulting in concrete tasks, projects or concepts on Non-Lethal Technologies. In this case the tasks include a project on Infra Sound and conceptions on foams and entanglements.

4. Infra Sound Project (Slides 5 & 6)

The goal of this project is the development of an Infra Sound-generator.
It started in May 1997.

* In phase 1 first step was the modification of an existing acoustic modulated Jet-burner. For the generation of higher infra sound levels there is a substantial need of energy required. For this purpose particularly oscillating combustion processes ar preferred because - determined by characteristic features of system - a certain part of energy is being converted in acoustical fluctuations of pressure. Our first goal concerned of the generation of a continuos combustion process. Heart of the technical equipment has been an acoustical modulated Jet-burner of type Gluareff operating with a gas mixture of propane/air.

* Second step included following series of tests:

- determination of the frequency spectrum of the original combustion chamber
- investigation of the frequency spectrum as for variable lengths of the resonant pipe,
- investigation of the frequency spectrum caused by modulation of fuel supply

These tests have been carried out.

* Making use of the results of these experiments and as planned in phase 2 to develop and constru a new demonstration model, we have come to the decision that this one will be based on a system of generating acous pressure waves. Our goal concerns sufficient high energy in combination with frequencies lower than 20 Hz.

* A look at our time-schedule presented by slide 6 shows that we will finish this project in November 98.

5. Concepts (Slides 5 - 16)

5.1 Materials

At this time the following material will be applied

Polyurethane

Polyamide

Polyester

Thermoplastic Elastomers

Phenolic Resins   and will be thought about

Biodegradable Substances

With regard to the application of biodegradable substances there could be solved problems like cleaning-up.

5.2 Principally Characteristics of the Technologies

Before the description starts there is to point out some main differences between the technologies which are of interest.

* The polymer or the polymer mixture can be commercial available as a finished product like a granulate (one Container system), or it has to be developed from basic materials on the basis of a polymeric process which results in a reaction polymer.

I prefer the second way because the reaction process is exothermic, so the course of reaction does not depend on any additional energy supply, the resulting material is a molten mass.

H wever using a granulate there has to be an energy transfer to the material in order to become molten. As the thermal conductivity of polymers is rather low there is some time to spend on it. Only the employment of micro waves would make sense.

* Differences between processes which use a solvent and processes which are solvent-free, are to separate. It is my intention to make more use of solvent-free operations.

* With regard to the energy supply for dispensing, pressure can be inside the material system as a system parameter for instance in case of a super critical fluid or the generation of pressure takes place using pumps or gas-generators.
On this occasion there will be a short description of the following four basic processes:

- Solvent-Process
- Super Critical Fluid-Process (SCF)
- Reaction Injection Moulding (RIM)
- Gas Generator-Process

5.3 Basic-Technologies

- Solvent-Process

Two polymeric substances are dissolved for instance by hydrochlorofluorcarbon (one-container system) and are under a certain pressure for dispensing.

- Super Critical Fluid-Process (SCFP)

Two basic materials are dissolved for instance by a fluid like carbon dioxide under super critical conditions (one container system). Although there is a molecular contact between the both substances, no chemical reaction results of it. As soon as the pressure will be reduced leaving the super critical region it occurs a chemical reaction and the formation of a new polymer.
It should be mentioned that the basic products also could be separated from each other in different containers including different solvents.

- Reaction Injection Moulding (RIM)

This equipment is more complex and includes the following components:

- two vessels contain the basic materials
- two high-pressure pumps
- a mixing-chamber

- some control-valves and nozzles and finally
- a dispenser.

RIM is a batch operation. The both basic materials are liquid and are stored, separated from each other, in heated vessels. The liquids are pumped under high pressure into the mixing-chamber, the heart of RIM-process.
What takes place here is called „high jet velocity impingement mixing" and is characterised by a very strong intensity. As a rule the reaction rates are so high that the reaction takes place even when the monomers are being mixed. The reaction product can be dispensed immediately.

- Gas Generator-Process

The operation is similar to the one described before. More or less only the both pumps will be exchanged for one or several gas-generators. This means there is a formation of a reaction polymer.

There is an alternative option using gas-generators. Instead of manufacturing a reaction polymer, a finished polymer could be employed as a basic material. Polymer granulate will be solved by a solvent to create a solution of high viscosity.
Under circumstances the solution and the nozzles have to be heated up.

- Unexpanded thermoplastic spheres

Compared to all processes described before the following method is rather different. Unexpanded polymeric spheres (beads) which consist of tiny liquid gas droplets encapsulated in a thermoplastic polymeric shell will be used. Under exposition of hot gases caused by gas generators, the thermoplastic shells soften at the same time as the liquid gas vaporises. The increased pressure causes expansion of the spheres to more than 60 times of their initial volume.
A large number of these spheres is inside a bag like an air-bag which is being blown up by several gas-generators and is being filled up. Due to closed contact between all the spheres the result is a cellular foam.

I want to add my personal view about these technologies .
RIM- and Gas Generator-Process show a very important advantage, because these processes are solvent-free. Therefore both operations are point of main efforts of our concepts at ICT. Nevertheless I will speak about examples including all described technologies.

5.4 Examples of Basic-Technologies in combination with special Materials

- Solvent-Process

At this time there are applicable blends of elastomers and thermoplastic resins dissolved by hydrochlorofluorcarbon (HCFC) and used for the generation of sticky foams. HCFC is an acceptable interim solution.
This is a or container system under pressure.
Also thermoplastic elastomeres being mixed with HCPC show an additional option, this could be a Co-Polymer like for instance TPE-O or TPE-E.
However to find the right solvent could be a problem.

- Super critical Fluid Process (SCFP)

Polyol and Diisocyanate are the liquid raw materials. Both will be dissolved by Carbon Dioxide (CO_2) characterised by super critical conditions. As soon as there is a reduction of the pressure leaving the super critical region, it starts a chemical reaction which results in the formation of polyurethane.
Probably this process can be applied to further basic materials.
Application is to the manufacture of foams and entanglements.

Reaction Injection Moulding (RIM)

In this case Polyol and Diisocyanate are basic materials again. The reaction rates are so high that reaction takes place even when the monomers are being mixed (In situ Polymerisation) and result in polyurethane.
This process also can be applied to the manufacture of further polymers like Polyamide or Polyester.
Applicable to the manufacture of foams and entanglements.

- Gas Generator-Process

- Reaction Polymers like a Polyurethane and a Polyamide can be manufactured, applicable to make foams and entanglements.
- On the basis of a Phenol and an Aldehyde, both in aqueous solution, there is a preparation of a Reaction Phenolic Resin as a result of a polycondensation. An important goal is to create a biodegradable foam.
-Small not expanded beads made of polystyrene have been known for some time. At this time there are available further thermoplastic polymers which can be applied to build up foams within big bags.
- Cyanogen Acrylate could be an interesting one-component for spraying of entanglements.

6. Potential Operational Areas (Slides 17 & 18)

There are many optional applications of Non-Lethal Weapons, particularly as to Peace Operations under command of the United Nations.
Several studies on NLW have been carried out, very important are the extensive investigations of FINABEL, AGARD and DRG. Each study includes information on scenarios, range of applications, where Non-Lethal Weapons could be applicable. The following both slides give informations of FINABEL and AGARD, that is to say the Non-Lethal Technologies with regard to appropriate operational areas. The study of DRG only makes difference between Anti-Personnel and-Material Weapons, nevertheless it supports the tendency of the other mentioned reports.

7. Optional Carrier Systems (Slide 19)

Slide 19 shows some examples of optional carrier systems which includes helicopters, missiles, land crafts and persons. There will be a comment on suitability being connected with technologies described before.
A Gas Generator is more qualified for small scale operations/area and as an instant energy source for the carrier units missile and person. On the other hand RIM-technology is more suitable for large scale operations/area and for land

crafts which can meet requirements as to size and volume of the technical equipment.

8. Combination of NLWs (Slide 20)

A combination of different Non-Lethal-Technology makes a lot of sense, to make sure that the effect for instance on crowds is as extensive as possible. It has been known for a long time that the effect on human beings depends on several parameters.

Basically there are material technologies like Sticky Foam and immaterial ones like High Power Micro Waves.

There are several strategies to employ NLTs. Technologies can work simultaneous, one after another or as peaks.

Slide 20 shows some examples of combined technologies.

9. Future study (Slide 21)

At last a comment on possible future trends with regard to described technologies. At this time at ICT there is a discussion on two ideas:

- Development of biodegradable foams and
- Development of an environmental friendly process on the basis of normal air as a blowing agent

Following slide shows the way as for the first task.

Definition

Non-lethal Weapons are: Technical means whose intention is to obviate (prevent or stop) hostile operations without causing death or lasting injury to human beings.

In addition, secondary effects caused by the use of those means to innocent people, property, and environment shall be minimised.

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Review on Activities in Germany

11/93- 4/95 MOD -> Study to DASA

⇓

8/95 Establishment of a BWB Study Group

⇓

9/96 Presentation in Hammelburg (Training Area of the German Army)

⇓

5/97-11/98 BWB -> 3 Projects:

Ranging Gun, Effector Net

Infra Sound

Audible Irritating Sound

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Technological Approach

⇓

Main Competencies at ICT

⇓

Scientific/Technological Basis of NLWs

- Particle Technology
- Polymer Technology
- Gas-Generator Technology
- Combustion Technology

⇓

Project-Ideas

⇓

Concepts of NL Technologies

- Infra sound without/with Irritant Materials
- Foams
- Entanglements

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Anti-Personnel Technologies

- Infra Sound without/with Irritants
- In-Situ Entanglements

Anti-Material Technologies

- Foams (sticky or rigid)

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Acoustic Infra Sound Project

Power -> Fuel

A Combustion driven Acoustic Generator, Type Gluareff

Phase 1:

1. Step: Modification of an Pilot Plant
2. Step: Realisation of a series of tests

Phase 2:

3. Step: Development and Construction of a new demonstration model

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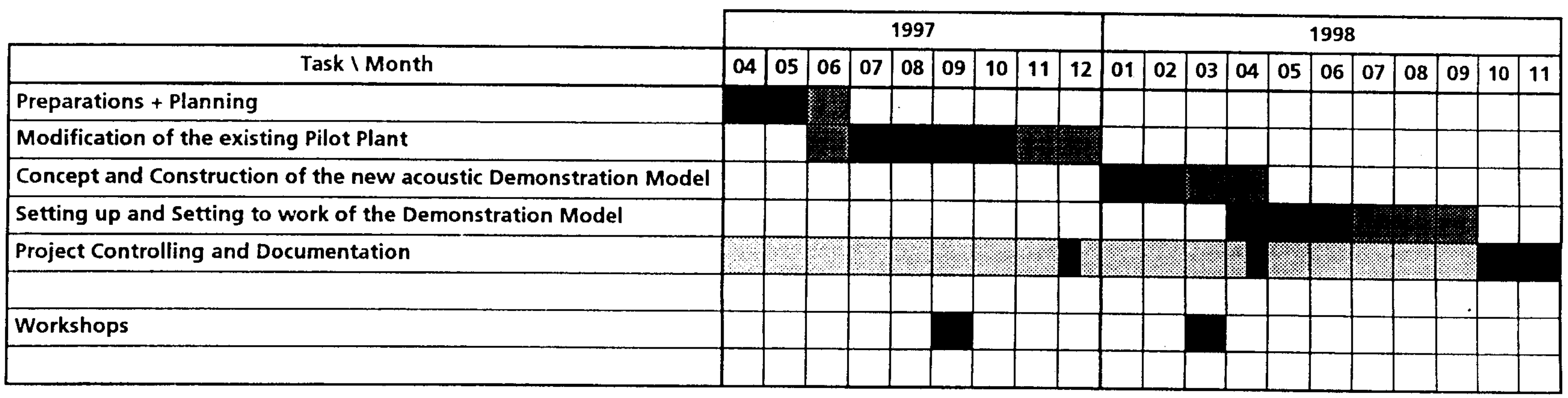
- Working Schedule of the Infra Sound-Project



Legend:

Planned Period of the described Tasks

Possible additional Time for the respective Tasks

Project Controlling

Materials

- Polyurethane
- Polyamide
- Polyester
- Thermoplastic Elastomers (Co-Polymers)
- Phenolic Resins
- Biodegradable Substances

Principally Characteristics of potential Technologies

- Finished Polymer <-> Reaction Polymer
- Solvent <-> Solvent-free
- Internal Pressure <-> External Pressure

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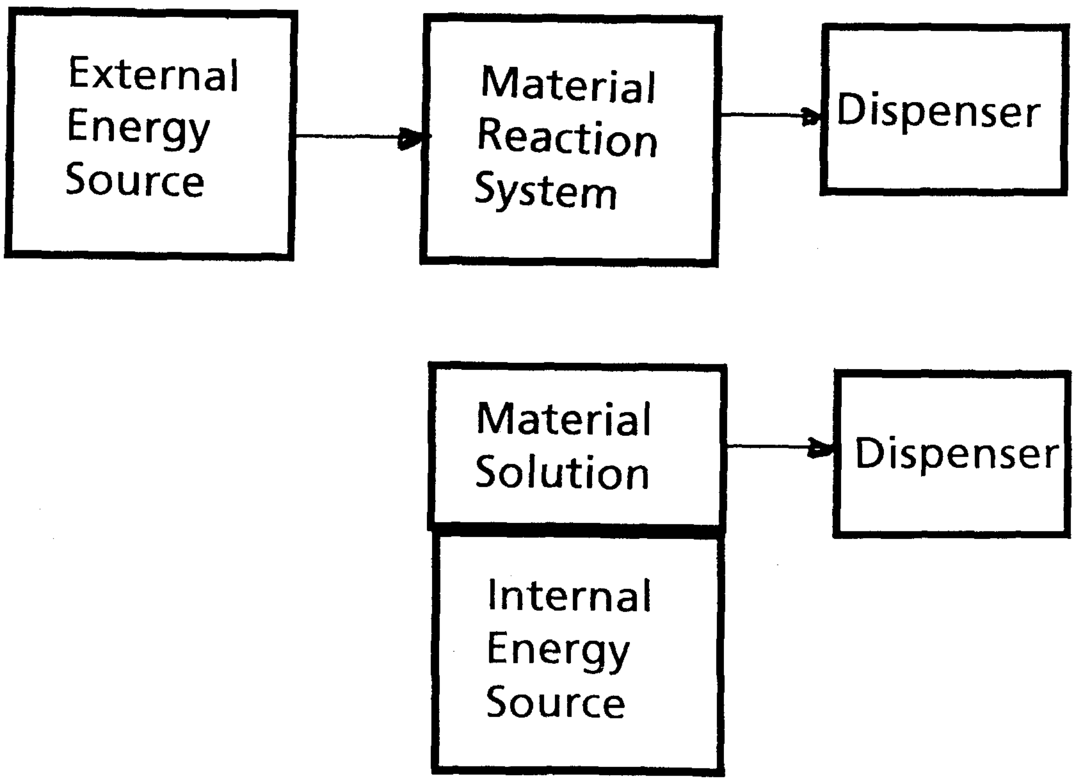
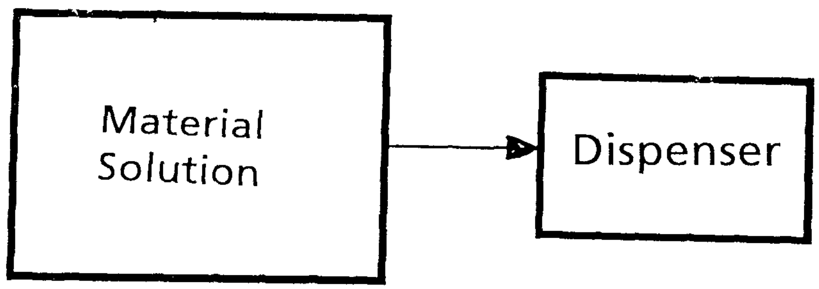
Principally Structure of Technologies

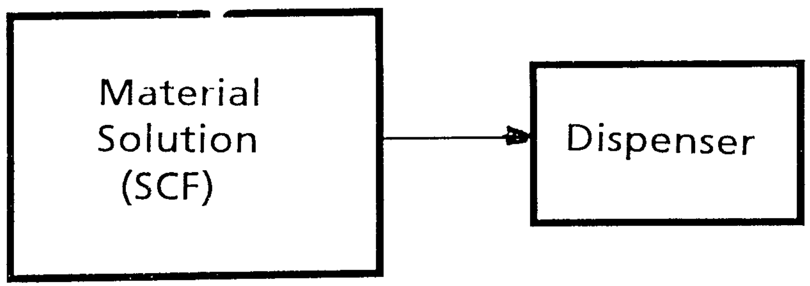


Solvent-Process



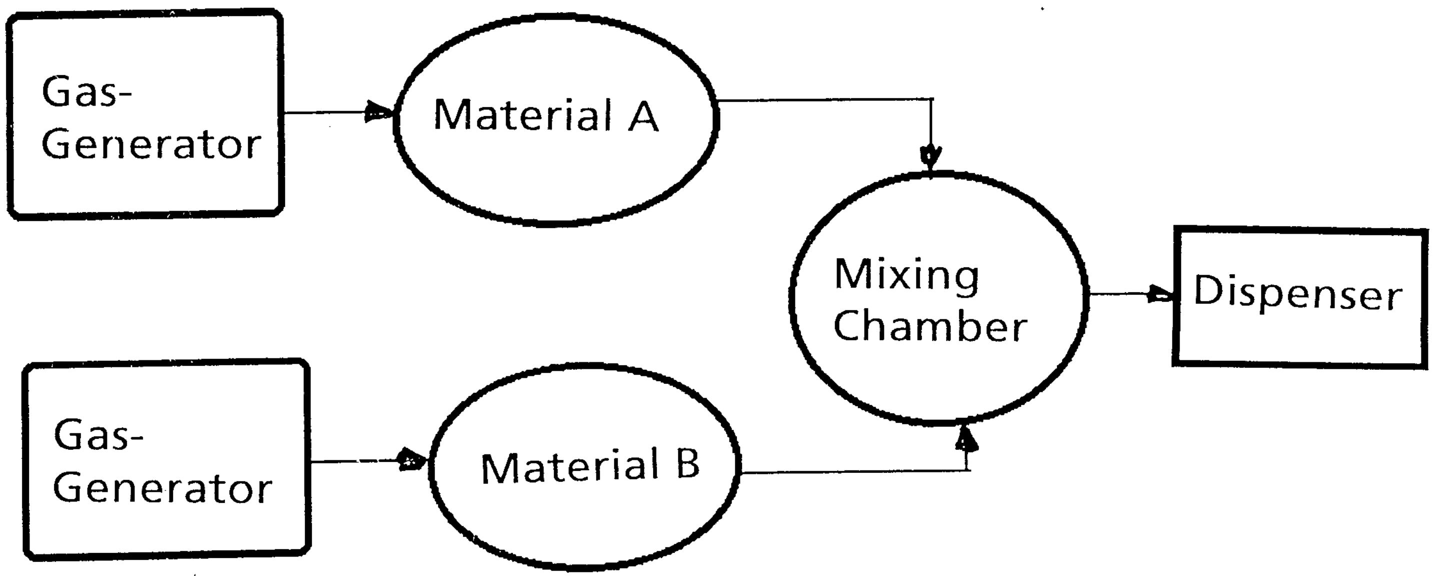
HCFC

Super Critical Fluid Process (SCFP)



Carbon Dioxide

Gas Generator-Process



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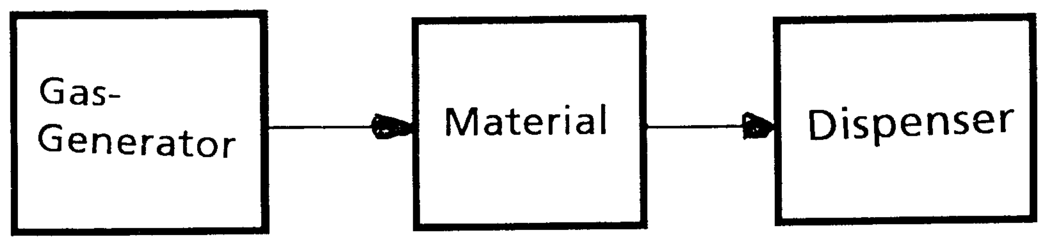
Basic-Technologies

- Solvent-Process
- Super Critical Fluid-Process (SCFP)
- Reaction Injection Moulding (RIM)
- Gas Generator-Process

Gas Generator-Process



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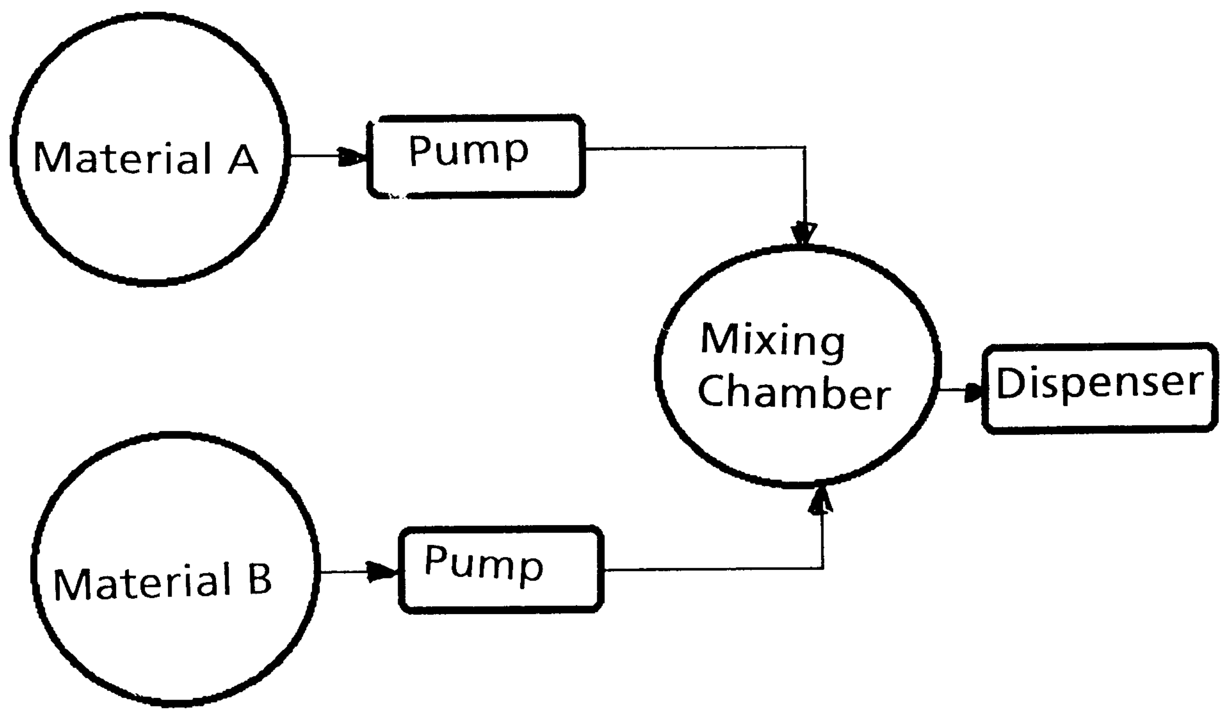
Reaction Injection Moulding (RIM)



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Technology	Material	Application
->Solvent-Process	Thpl & Elast.	Foams
->Super critical Fluid Process (SCFP)	PU/R/,......	Entanglements, Foams,
->Reaction Injection Moulding (RIM)	PU/R/, PA/R/,PES/R/ PU/R/	Entanglements Foams

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Technology	Material	Application
->Gas Generator-Process	PU/R/, PA/R/	Entanglements
	PU/R/	Foams
	Phenolic Resin/R/	Foam
->Not expanded Spheres-Process	Thermoplastics	Foam in Bag
->One Component Process	Cyanogen Acrylate	Entanglements

Applications recommended by FINABEL

Technology	Crowds	Terrorists	Soldiers	Immobilization of Vehicles	Electronics
Infra Sound	⊗				⊗
Foams	⊗	⊗			
Entanglements	⊗	⊗	⊗	⊗	

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Applications recommended by AGARD-AAS 43

Technology	Large Crowds	Personnel in Foxhole	Roman Bridge
Infra Sound	⊗		
Foams	⊗	⊗	⊗
Entanglements	⊗		

Examples of potential Carrier Systems

Technology	Helicopter	Missile	Land Craft	Person
RIM	⊗	---	⊗	---
Gas-Generator	X	⊗	X	⊗
SCF	X	---	X	X
Solution	X	---	X	X

⊗ especially favourable

X favourable

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Examples of Combined Technologies

Strategy	material	immaterial	material/immaterial
Simultaneous	IP / ET	IS / SS	IP / IS
One after another	CW / IG	IS / HPM	SF/ IS
Some Peaks	CW / IG	IS / PE	IG/ PE

IP: Irritant Particles; IG: Irritant Gas/Spray; IS: Infra Sound;

SS: Super Sonic; CW: Coloured Water; HPM: High Power Micro Waves;

SF: Sticky Foam; ET: Entanglement; PE: Pulsed Energy;

Usual Foams

$\Downarrow$

Foams which fill up Bags

$\Downarrow$

Biodegradable Foams

Virtual Human

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Abstract

A computational model of the human, the *Virtual Human*, is being developed at the Oak Ridge National Laboratory (ORNL). The *Virtual Human* will provide the capability of evaluating the effectiveness and safety levels for Non-Lethal technologies. This model could also be viewed as an engineering design tool for the development of new non-lethal technologies as well as countermeasures. In addition, the Virtual Human will be useful for evaluating human responses to new scenarios of equipment and operational conditions. Its use will minimize the need for actual human subjects being involved in testing and simulation.

It has been said that while the 20th century was the century of physics, the 21st century will be the century of biology. The Oak Ridge National Laboratory is uniquely positioned to play a leadership role in the grand challenge level problem of linking the physics and biology of humans in ways that will permit new avenues of research relating to human function and biomedical applications. The *Virtual Human* is being developed at ORNL using a three-dimensional representation based on the Visible Human data set. The *Virtual Human* will be a research/testing environment having an integrated system of biophysical and other models, data, and advanced computational algorithms. It will have a Web-based interface for easy, rapid access from several points of entry. It will serve as a platform for national and international users from governments, academia and industry to investigate the widest range of human biological and physical responses to stimuli be they biological, chemical, or physical. This effort will go far beyond the visualization of anatomy to incorporate physics, such as mechanical and electrical tissue properties and biology from physiology to biochemical information, into the platform so that responses to varied stimuli can be predicted mechanistically and results viewed three-dimensionally. Because numerous anatomical and biokinetics models, databases, informatics and visualization capabilities are locally available for integration, as well as requisite supercomputing and mass data storage devices, ORNL is better equipped to lead the development of this concept than most scientific organizations in the world. However, many other organizations have much to contribute to the final development of the Virtual Human, both from the user requirements perspective and the technical development side. Therefore, we are inviting groups that have experience in related topical areas to join with ORNL in order to help refine the focus of this program and contribute to its development.

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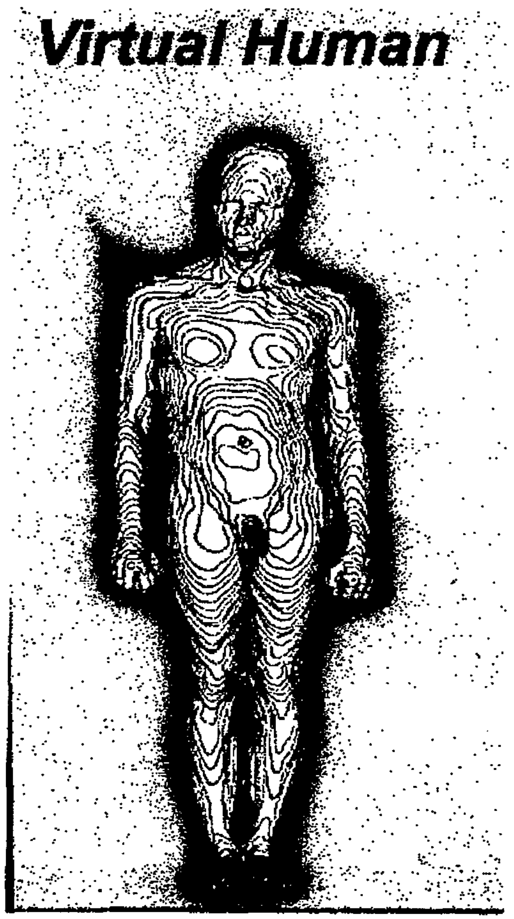
[1]Operated by Lockheed Martin Energy Research Corp., for the U.S. Department of Energy under Contract No. DE-AC05-96OR224642.

The Virtual Human: A Diagnostic Tool for Human Studies and Health Effects in the Twenty-First Century



Oak Ridge National Laboratory

Clay E. Easterly,
M. J. Maston
& the
Oak Ridge Team

Non Lethal Defense III

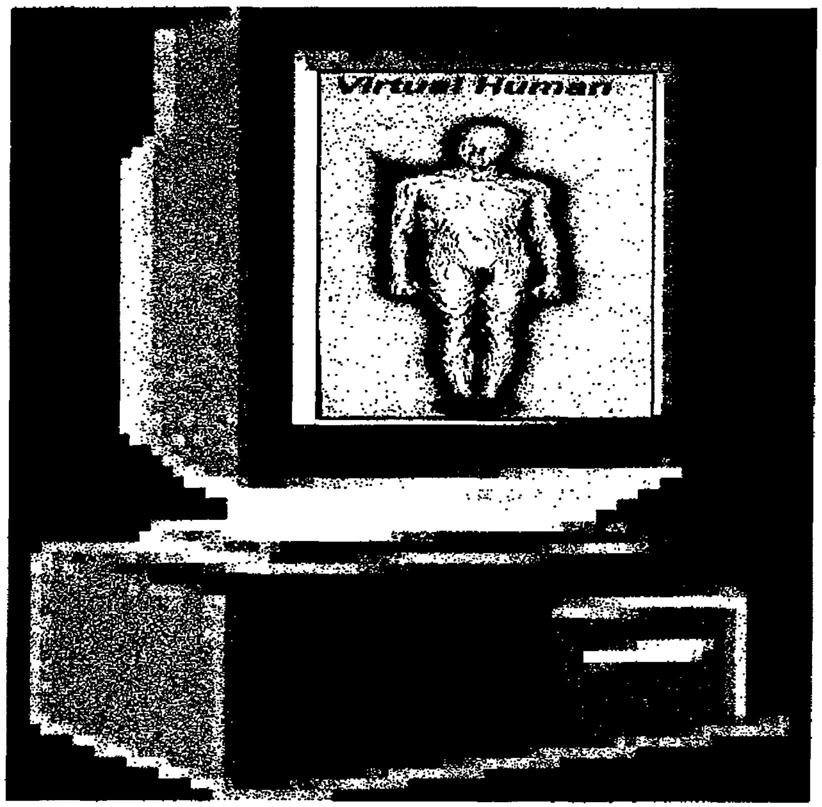
25 February, 1998

Laurel, MD

Purpose of Presentation

- Provide initial public discussion of the Virtual Human program
- Solicit feedback
- Identify potential collaborators

The Vision



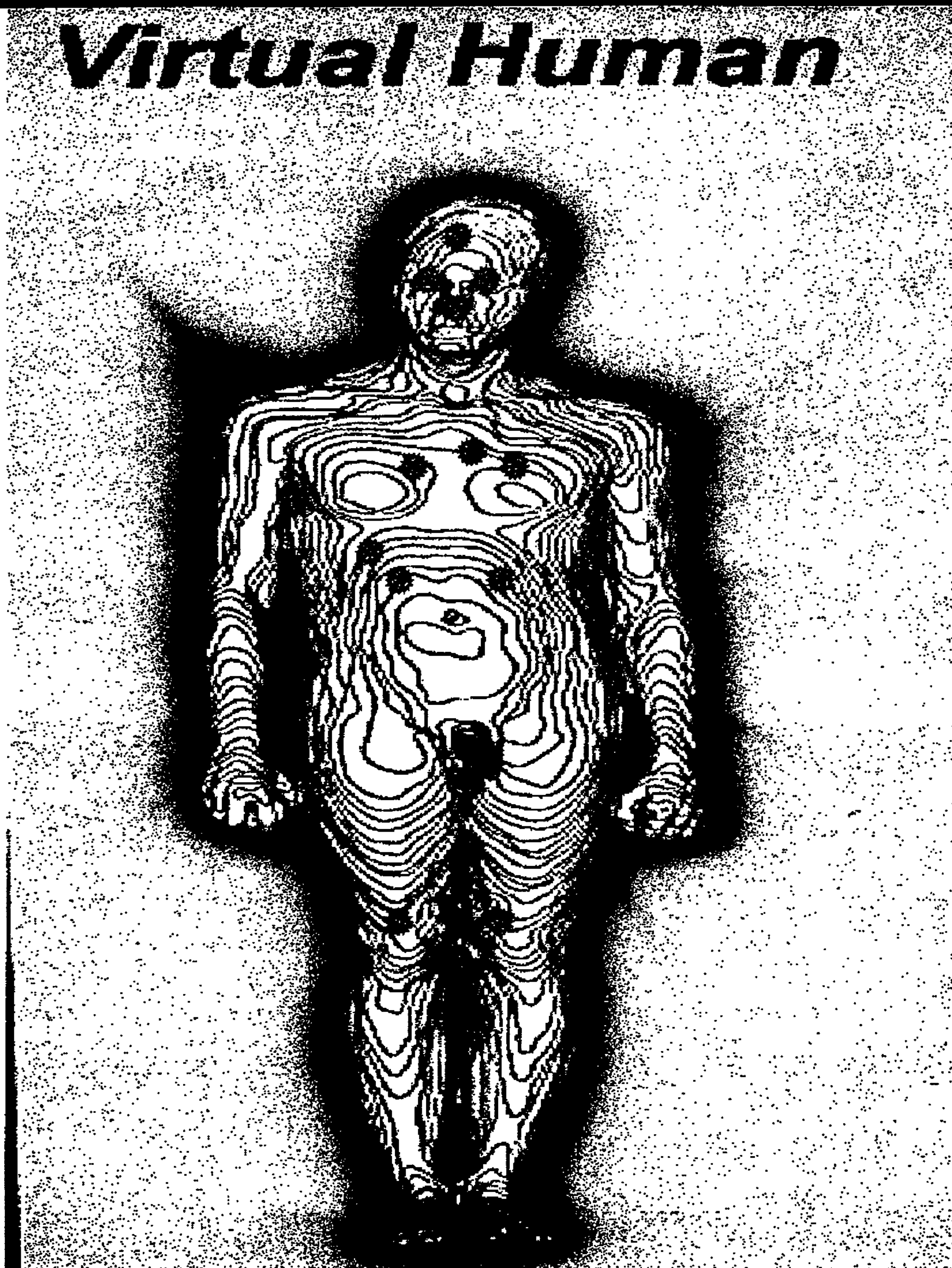
- Model the Human Body with Fidelity
- Far Beyond Anatomy
- Link Biology, Physics, Chemistry & Computational Science
- Wide Ranging Applicability
- Sponsor Adaptability

VISION (CONT'D)

- Complete system
  - physiological
  - cognitive
- Requires many collaborators
  - multiple medical communities
  - national effort
- Collaborators retain ownership of work
  - function as repository for specific expertise
- Differs from similar sounding efforts

VISION (CONT'D)

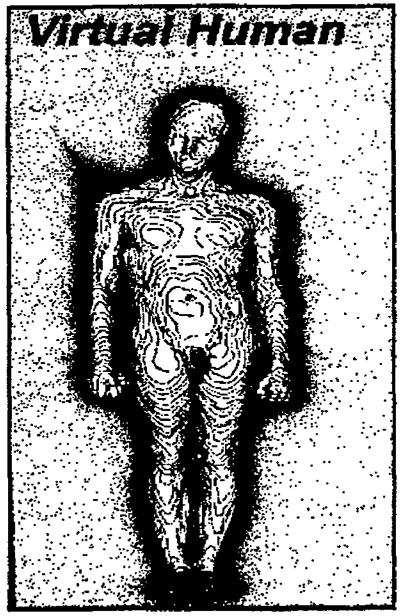
- National Laboratory role
  - coordination
  - integration
  - specific modeling
  - computational networking



Plenty of real estate available for research (and development)

- Known research ongoing

Overall Effort



- Workshops: Basic approach
- Solicit collaboration
- Identify existing data/models
- Model specific systems
- Model integrated systems
- Identify gaps
- Early prototypes 2005

- NIH, NLM, Medical Community
- DoD-Training, Simulation, Countermeasures
- Transportation Safety
- Civil Law
- DOE, Basic Science

- Cost at ORNL: Year 1 & 2 $2-4M; Year 3-10 $5-10M; Year 10+ ?
- Collaborators: (US & International)

  National Labs

  Universities

  Private companies

APPLICATIONS OF MODEL

- Explore interface between engineering and medicine
- Advanced monitoring capabilities
  - injectable multifunction sensors
  - transmit data to model
  - time course of diverse information
  - sensor fusion via physiological model
  - evaluate effects of single new medications
  - set dosage and type for controlling multiple conditions

PRESENT AGENDA

- Two levels of workshops
  - small gatherings to focus on potential user needs
  - larger, public meetings to inform community and gain feedback
- Face-to-face with potential collaborators
  - Team building

PRESENT EFFORT

- Identify and support existing research
- Identify and fill voids in research
- facilitate common architecture to integrate research

Why ORNL?

Most Complete DOE Multipurpose Laboratory
In-House Collection of World Class Experts to Lead Effort

- Biology
- Engineering
- Computational Physics
- Visualization
- Risk Assessment
- Computer Design

- Human Factors
- Computational Biology
- Computational Mathematics
- Internal Dose Modeling
- Toxicological Data Bases
- Supercomputing Facilities

In Addition...

- Long-term commitment (Institutional Memory)
- History of developing and operating "User Facilities"
- Ability to protect intellectual property of users
- Significant up-front investment already in-place
  - genome project
  - super computing
- Ability to compartmentalize work (Open, Proprietary, or Classified)

Summary

- Virtual Human is a long-term program
- Planning extensive and complex
- Initial ideas of application numerous
- ORNL team believes, using example of Internet, most applications may not surface before useful model is completed
- Collaborators are being sought

Biological Effects of Non-Lethal Weapons: Issues and Solutions

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1. Introduction

Military peace keeping, humanitarian efforts, and missions other-than-war have become increasingly common. In such operations, many dangers exist to the troops, yet the use of lethal force is often not justified or acceptable. This conference in concerned with new non-lethal options for applying military force.

This new requirement has been addressed by the United States Department of Defense in a policy statement for Non-Lethal Weapons (NLWs), in which such weapons are defined as "**weapon systems** explicitly designed to **incapacitate personnel** or materiel while **minimizing fatalities, permanent injury, and undesired damage to property and the environment**" (DoD Policy Directive 3000.3). The development and fielding of new weapons that fit this definition will require much work using many approaches. I will focus on the biological effects of NLWs.

a. What are bioeffects?

Broadly, bioeffects include any effect an internal or external stimulus has on part or all of a biological organism. A random sample includes: DNA damage, depolarization of an excitable membrane, muscular contraction, loss of equilibrium, sensory stimulation, sensory blocking, emotional response, nausea, fear, increase in heart rate, avoidance, cellular damage, altered metabolism, confusion, loss of consciousness, convulsions, death. Bioeffects can be as simple and hard to detect as the ionization of a biomolecule, such as DNA, or as complex and obvious as a grand mal seizure. They can be as innocuous as a recognition of a pleasant scent or as harmful as stopping of the heart & death. In fact, as living human beings almost all that we are and all that we will become is determined by bioeffects.

b. Who are bioeffects specialists?

Bioeffects specialists include medical doctors, physiologists, psychologists, behavioral scientists, veterinarians, anatomists, neuroscientists, biologists, epidemiologists, theoreticians and others, all concerned with the effects of any stimulus (biological, chemical, or physical) on part of all of a biological organism.

2. How are bioeffects important to NLWs?

DoD Policy Directive 3000.3 on policy for NLWs provides three general requirements for a satisfactory NLWs program: Technical feasibility, operational utility, and policy acceptability. Bioeffects form part of the foundation for meeting each of these requirements.

a. Technical Feasibility

Technical feasibility means that the science, engineering, and manufacturing capability exist to build a desired non-lethal system. Issues of cost, size, weight, logistics, and maintenance predominate. Bioeffects are involved in providing the requirement parameters for the system. In an orderly process, bioeffects review and research would: (1) determine areas of human vulnerability; (2) develop biological criteria for biological effects on the target, recovery of the target, and long-term medical impact on targets, operators, and bystanders; and then (3) provide data to the engineers so that a system can be built to optimally expose the target and limit collateral damage. Too often, the process is anything but orderly, and NLW systems are built on the minimally supported belief or hope that if you make it hard enough, bright enough, loud enough, smelly enough, etc., it must do something. For anti-material NLWs, it is often overlooked that these weapons could also impact humans who are operators of the weapons, are using the material being destroyed, or are merely bystanders.

b. Operational Utility

Operational utility refers to the usefulness of the NLW, and, in the context of bioeffects, only applies to anti-personnel NLWs. The important question here is "What do commanders and military troops consider to be useful bioeffects?" In the short list I provided earlier, some of bioeffects are too minimal to be useful and others to extreme, but where do you draw the line. DoD Policy Directive 3000.3 refers to "incapacitation" as a goal of NLWs; but, what does this actually mean? Some might consider "incapacitation" to include a disinclination to perform a task (such as throw a rock or enter a forbidden area), whereas others may consider "incapacitation" to mean the impossibility of performing any task. The only U.S. military definition of "incapacitation" that I have found comes from the Joint Service Manual for NLW Tactics, Techniques, and Procedures and states:

> "Incapacitation is achieved when weapons effects result in physical inability (real or perceived) or mental disinclination to act in a hostile or threatening manner. In keeping with the guiding principles of NLWs, this incapacitation should be readily reversible; preferably, self-reversing through the passage of time."

In addition to achieving a non-lethal goal, i.e., incapacitation, operational commanders are also interested in the <u>parameters</u> of the incapacitation. Some relevant parameters include: dose for main desired effect; can the effect be tuned; time until initial effect; duration of effect; synergy with other factors; reversibility versus irreversibility of effects; side-effects to targets; undesired collateral effects; environmental effects; and susceptibility to countermeasures.

Bioeffects analysis by review, research, and modeling is important to addressing all of these parameters.

An extremely important point is that bioeffects specialists need to communicate with the military commanders and operators who define "Operational Utility" by setting the parameters and criteria for a "useful" NLW. There is a vast number of possible bioeffects and parameters of bioeffects for proposed NLWs. Bioeffects specialists cannot test them all; they need interaction with the operators to help focus their efforts on useful bioeffects and parameter criteria.

c. Policy Acceptability

The third requirement for an acceptable NLW is Policy Acceptability. This is an extremely complicated topic in which bioeffects have two major roles. For anti-personnel NLWs, the policy that NLWs should "minimize permanent injury" is primarily a bioeffects issue. The immediate effects of an NLW are part of its evaluation as having operational utility, but the time to and extent of recovery from the weapon's effects are important criteria to determine policy acceptability. To illustrate that bioeffects issues can be "show-stopper", one only need remember that the Laser Countermeasures Systems (LCMS) Program was cancelled in 1995, just as it was about to go into production, because of the bioeffects issue of eye-damage and blinding. Will the use of proposed acoustic NLWs be similarly limited because of concern over the possibility of ear damage or deafening?

The second role of bioeffects in NLW policy setting, concerns the long-term medical consequences of exposure to the NLWs for anyone exposed, including the operator, the target, and bystanders. If occupational exposure standards exist for the particular agent being used, as they do for many types of noise, radiation, and chemicals, then these standards can be followed, at least for operators and non-combatants. If the exposures are sufficiently novel that no health standards exist, for example certain types of directed energy, then standards need to be developed. Possible delayed effects, such as cancer, neural, or reproductive consequences need to be considered, if we are to minimize future litigation and public outrage. For example, one of the chemical components of sticky foam, butadiene, has been shown to cause cancer in animals; it is claimed that short term exposure to humans is not hazardous, but have sufficient bioeffects studies been done to assure policy acceptability? These concerns are relevant to anti-material technologies as well as anti-personnel application of NLWs

3. The Variability of Human Responses and the Probabilistic Nature of Bioeffects

a. Biological Variability and the Safety Margin

Because of biological variability there will always be uncertainty in predicting the biological responses to NLWs. Even among a consistent population of humans, such as a group of young adult males, there will be a variability in responses to the same stimulus. When the variance of the population increases, for example by adding persons of differing sizes, ages, weights, frailty, health, and both sexes, so will the variability of the population response to most NLWs. Within the context of this variability, the probability of different responses can be

estimated for different amounts or doses of the applied energy or chemical. The difference in dose required to produce a desired effects (e.g., incapacitation) and an undesired effects (e.g., permanent injury) is often called a safety margin. For an NLW with a good safety margin, the dose that produces the desired effect in most people would produce the undesired effect in none. A poor safety margin results if a particular dose produces both desired and undesired effects. The principles of such considerations are well developed in the disciplines of pharmacology and toxicology.

Therefore, biological responses to non-lethal weapons will be probabilistic at best and may be extremely uncertain. This fact is true for target, operator, and bystander effects. One of the roles of bioeffects specialists is to estimate "dose response" curves for proposed NLWs, so they can be used to access operational utility and policy acceptably of the NLW before acquisition and deployment.

b. Other Sources of Variability

Although it is true that bioeffects can be variable, it should be noted that they are not the only source of variability in the use of a NLWs. The amount of energy or chemical emitted from the weapon itself can be variable because of manufacturing differences, improper maintenance, and operator error or choice. The transmission of the energy from the weapon to the target is affected by variations in aiming, beam spread, and intervening conditions such as rain, wind, temperature, terrain, and structures. Coupling of the energy to the target can be passively affected by the target's size, orientation, and clothing as well as by active countermeasures purposively employed by the target. All of these factors affect the actual does delivered to the target and precede the biological variability and probabilistic nature of response, described above.

c. Remote Vital Signs Monitor: One approach to reducing the variability

In addition to conducting research to estimate the uncertainty in the biological effects of NLWs, another goal is to reduce the uncertainty. For maximal effectiveness and safety, an assessment of the desired effect should be available. Is a fallen adversary faking, incapacitated, unconscious, or already dead? For human targets some type of monitor to remotely determine vital signs (heart rate, respiration) would be useful. Controlling the application of the NLW energy on the target could be a key to insuring that the weapon produces its desired effect, yet does not pose too high a risk of causing lethality or permanent injury. Such devices are available, at least in brass board configurations, and should be developed as fieldable systems.

4. Approaches to Bioeffects Testing: Issues and Examples

In the first part of this paper, I have described the general importance of bioeffects to meeting the requirements for NLWs. In order to create validated models for effectiveness, recovery, and health consequences, the full range of techniques for the study of biological effects will be needed. Many of the needed techniques are fairly standard in the medical world. However, the nature of some of the non-lethal technologies make such assessments more complicated, requiring special facilities and equipment. I will give two types of examples of

approaches taken to study NLW bioeffects, one dealing with acoustics for anti-personnel NLWs and one dealing with ultrawideband radiation for anti-material applications.

a. Investigating the Non-Lethal Weapon Potential of Acoustic Energy

Historically, acoustic energy is reported in the Old Testament as having an anti-materiel effect on the walls of Jerico, but it was hardly a non-lethal use of acoustics, since the walls "came tumbling down" and everything in the city was "utterly destroyed". In his work "Life of Marcus Crassus", Plutarch described the use of bells and drums as a psychological NLW. More recently, Rock Music was used to annoy Manuel Noreigea in Panama. But despite its supposed historical roots and the attention it has received in recent articles in the popular media, there is very little scientific research on the usability of acoustics as an NLW. Research on acoustics at Brooks AFB has been sponsored by the Defense Advanced Research Projects Agency (DARPA) and by the U.S. Army's Armaments Research and Development Engineering Center (ARDEC).

Current ideas for NLWs using acoustics employ neither trumpets, drums, bells, or boom boxes. One idea is to use high intensity infrasound. Obtaining sources on which to conduct research is one of the biggest problems of NLW bioeffects testing. For initial work, we were forced to borrow an enormous acoustic test device developed by the Army Research Laboratory for environmental research. In order to abide by animal use regulations, our team moved a trailer based mobile laboratory to the desert location of the source. A team of 10 scientists traveled to the site, bringing research animals and instrumentation. The conditions were rather difficult, but excellent data were obtained.

Since there were no suitable indoor infrasound test facilities that would allow the testing of animals, we constructed a special pressure chamber, named the infrasound test device (ITS), in which we could examine the effects of infrasound at different frequencies on both anesthetized and awake subjects under controlled condition. A combination of field and laboratory studies, using different equipment, are also used to test other frequencies of sound.

The procedures used to test infrasound illustrate one of the main problems of bioeffects testing of NLWs. Especially for directed energy NLWs, the actual sources being developed for field use are often too big, hazardous and/or unreliable to be brought into the laboratory for systematic, controlled bioeffects testing. Doing a limited amount of science in the field is possible, but far too expensive to collect the extensive data needed for answering effectiveness, recovery, and health questions required for NLW bioeffects research.

With regard to acoustics, the primary health and safety issue relates to possible hearing damage of the target. For this reason, we do hearing tests on our animal subjects before and after acoustic exposures and, if there are indications of hearing threshold shift, for several weeks following the exposure

b. Investigating the Health Hazards of a Proposed Anti-Materiel NLWs

Many laboratories have reported developing electromagnetic weapons to disrupt

electronics, including stopping vehicles with electronic ignitions. In particular pulsed high-power microwaves (HPM) and ultrawideband (UWB) radiation are being considered. These "anti-material" weapons would most likely be used on systems that were being operated by personnel and so human exposures would be inevitable. Thus the possible health consequences to both the operator of the weapon and the people in the vicinity of the target are important issues.

Biological research on both UWB and HPM requires access to RF sources, and, as with acoustical research, while some research is conducted in the bioeffects laboratory using specifically designed lab sources, some must be conducted at the engineering laboratories were the sources are being developed. Thus, again our mobile lab is required. UWB bioeffects research started in 1991 and, because this type of radiation had never been tested before, we did a variety of quick tests to look for any dramatic effects. We found none, so developed a plan to examine the possibility of more subtle effects of UWB. The U. S. Army and Air Force research teams have completed studies on behavioral responses, cardiovascular effects, carcinogenicity potential, and induction of birth defects. A life time cancer promotion study and research on neurophysiological effects are still in progress. This work has been conducted on cellular and animal models ranging from bacteria, to yeast, to rats, to primates. To protect the people working with UWB, who are mainly employees of military establishments, the Tri-Service Electromagnetic Radiation Panel has issued an interim safety guidance for permissible exposure to UWB.

Most of the agents being considered for NLWs have been around for awhile and have already been subjected to extensive bioeffects analysis. However, other novel energies or chemicals may require a similar extensive analysis to that which I have described here for UWB.

5. Extrapolation from Animal to Human

The work on acoustics and UWB radiation at Brooks AFB currently exclusively uses animals. The use of animal models can provide general insight into the type of effects to be expected in humans, indications for thresholds and limits for effects in humans, and an understanding of the mechanisms of the effects; but, the question always remains of how well research using an animal model extrapolates to the human condition. Obviously, the best test subject is the human. Human use requirements are extremely strict, requiring multiple levels of review and approval as well as informed consent of the subject, but the insight provided from a carefully done human experiment can be well worth the trouble and risk and can provide the link that will allow math models to be developed and animal data to be extrapolated to humans with much greater predictive accuracy. Ultimately, experience from actual use of NLWs will provide information that will help improve the weapons themselves, as well as validate the models for future development.

6. Conclusion

Bioeffects specialists do not build weapons systems, they do not make policy, set rules of engagement, or pull the trigger during a conflict. However, they can provide information that will allow developers, policy makers, and operational commanders make better informed decisions

about the human impact of non-lethal weapons. Insufficient attention to bioeffects could lead to the development of expensive hardware that would be operationally useless, prohibited by policy, or both. Insufficient attention to bioeffects could lead to NLWs that produce unreliable or extremely variable effects. Inattention to bioeffects could also result in NLWs that too often produce irreversible damage to the target, and have long-term health consequences on the target, the operator, and bystanders. Considering these issues from an early stage of NLW development and including bioeffects specialists as partners on the NLW team will help assure the fielding of effective, safe, and acceptable new non-lethal weapons for military and law enforcement applications.

[1]DISCLAIMER: The opinions expressed in this paper are the author's and should not be interpreted as an official position of the U.S. Government.

[2]*Although no unpublished data are presented in this paper, it is noted that all animal research at the Air Force Research Lab is accomplished in accordance with approved protocols under "The Federal Animal Welfare Act PL 89-544; DOD Directive 3216 dated 17 Apr 95, Use of Animals in DoD Programs; and AFR 169-2, Use of Animals in DoD Programs" as implemented in Armstrong Laboratory AL Investigatory Handbook, dated 19 Oct 95, and all human research in accordance with approved protocols under AFI 40-402 "Using Human Subjects in RDT&E" as implemented in the Armstrong Laboratory Handbook for Investigators Involved in Human Experimentation, 40-1, May 95.)*

A Methodology Using Biosimulants to Describe Non-Lethal Weapon Effects on People

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Abstract

The response of biological systems exposed to Non-Lethal Weapons (NLW) is not well understood. The literature contains predominately anecdotal references to effects that have not been systematically studied and are subject to ambiguous interpretation. Without a clear understanding of the mechanisms by which the device effects couple to the target and evoke response modes of interest, there is no way to extrapolate the results of animal experiments to humans. In particular, for devices which radiate mechanical waves through the body, such as High Power Acoustic Beam Weapons (HPABWs), non-penetrating projectiles, and toriodal vortices; differences between humans and animals with respect to tissue properties, organ and cavity geometry, elastic properties of connective tissue, and frequency response of specific anatomical structures, strongly suggest that there will not be an obvious correspondence between response modes evoked in animals and humans.

Our approach analyzes conventional trauma databases to identify regions of the human body that may be susceptible to NLW effects and response thresholds that can evoke desired effects. Once the pathogenesis of a potential effect has been identified, experiments using insitu instrumentation and biosimulants configured to mimic relevant anatomic features are implemented. These experiments support development of analytical models that describe the physics of the interaction and which can ultimately be extrapolated to biological systems.

MRC has successfully applied various aspects of the proposed methodology to its ongoing DARPA/MRDC sponsored Simulation and Assessment of Musculoskeletal Trauma from Penetrating Wounds program (DAMD17-94-C-4099) and its DLA/DARPA/NRaD/MRC Sensate Liner Development for Combat Casualty Care program (N66001-96-C8641).

The Remarks of
General John J. Sheehan, US Marine Corps (Retired)
Former Commander-in-Chief US Atlantic Command
Former Supreme Allied Commander - Atlantic
At the Banquet for Non-Lethal Defense III
Johns Hopkins University Applied Physics Laboratory
25 February 1998

Two years ago, I challenged this group to give operational commanders more tactical options than forcing a young soldier to decide whether he shoots a rioter with a 9mm or M-16. Events of the last three weeks would seem to indicate I should have raised the cross bar and asked the question - how do we give the president of the United States more options than just bombing some one with stand off weapons? I would argue that for the same reason why we have not made much progress in the tactical non-lethal area is exactly why we could not use non-lethal weapons at the strategic level. It is because we have a bias toward kinetic weapons. We are willing to spend huge sums of money on improving kinetic weapons while at the same time we fight to allocate a few million to non-lethal weapons.

For fifty years we defined our security in a single dimension against a fixed opponent. It was the US and NATO against the Soviet Union. Foreign policy was a zero sum game. As a result the current U.S. military establishment is a highly evolved Industrial Age Institution. It was designed to operate in the post-World War II geo-strategic environment. A nation's power could be measured by combining its military and industrial strength. For the most part, change was gradual. The sudden collapse of the Soviet Union served as a clear indication that this model was no longer valid, and the non-military factors have gained a much more prominent position in how people define security.

Since the fall of the Berlin Wall, the geo-strategic environment we live in continues to change rapidly. Although military capability remains important, economic strength has replaced military power as the primary indicator of global influence. The nation-state has surrendered much of its power and influence to non-state actors such as the IMF. In the "developed world," permeable borders and trans-national institutions have gained tremendous influence in what were once the exclusive domains of national governments.

Today's decisions by Washington are increasingly based on America's interdependence in a global economy. While US residents constitute only 5% of the global population, they "own" 50% of the world's $15.5 trillion retail mutual and private pension fund assets.

From an American perspective, the requirement to be globally engaged, both diplomatically and militarily, is a natural outgrowth of the globalization of our economy. However, in the eyes of most non-Americans, globalization means much more than just cross-boarder economic activity. Globalization to them connotes the Americanization of the world - or as many in Europe would argue as a result of last week's events - Thucydides dictum Large nations do what they can small nations suffer what they must. Many in the developing world globalization as a serious threat to their societies and cultures. Thus, many are quick to react negatively to globalization and in some case attack the symbol of their anger and unfortunately often times it is an American citizen. Or as happened last week in Indonesia where ethnic Chinese representing only 4 percent of a 200 million person population became the scapegoat of the Indonesian economic crisis in part because they hold 70 percent of the nation's wealth and many were injured during the anti-Chinese riots.

Weak central government, combined with the explosion of information technologies needed to manage a modern economy and government, are the primary

reasons why many countries like Albania just a year and a half ago can quickly collapse. Tirana lacked the modern "software" needed to monitor its own monetary system. Nationwide "Ponzi" schemes outmaneuvered the central government's ability to regulate its own currency. The result was a total collapse of the government's authority, widespread chaos, and a wave of illegal migration and weapons across unregulated borders that threatened regional stability.

Like Albania, the vast majority of mankind has not benefited from the profound changes in the developed world. Rather, most "countries" in the developing world continue to struggle with rapid population growth, widespread famine and disease, environmental damage and governments too weak or corrupt to deal with the needs of their populations. These factors have generated increased social unrest and massive migration - not only from the failed states that dominate the evening news, but also from the failing states that are usually ignored until they too collapse.

Global demographics will force us to pay closer attention to global problems that have traditionally posed only an indirect threat to our security. Population growth is quickly becoming one of the more important variables in the emerging security environment. Those of us born before 1950 have seen more population growth than in the previous four million years.

At the beginning of the industrial age there were an estimated 7 million slum dwellers today there are an estimated 700 million people living in slums.

Civil strife in countries such as Haiti, Bosnia, Cambodia and Zaire generates enormous pressure on its population to leave home for a better life abroad. This, in turn, creates tremendous pressure on likely destination countries - like the United States - thus turning illegal immigration into a security problem.

The scale of these demographic changes is often lost on those of us who are fortunate to live in the developed world. Most of us would be surprised to learn that we could shrink the earth's population to a village of 100 people with all existing ratios remaining the same, in that village of 100 there would be 57 Asians, 21 Europeans, 14 people from the Western Hemisphere (North & South America) and 8 Africans. Seventy of these villagers would be non-white. Thirty would be Christian. Fifty percent of the entire wealth would be in the hands of 6 people - all from the United States. Seventy people would be unable to read, fifty would suffer from malnutrition, and 80 would live in sub-standard housing. Only one person in the village would have a college education.

What we are seeing is really a growing income gap between the rich and the poor. Never before has the wealth disparity been great. And because of the widespread availability of global communications, never before has this disparity been equally visible to those at the top and bottom of the economic continuum. Unlike the ideologically based, correlation of forces model used during the Cold War, just ten years ago or its balance of power predecessor, was an industrial age function - today's security challenges are multi-dimensional and often transcend the power and authority of affected nation-states.

Consider for a moment a recent report from the World Watch Institute, what does it mean for you if I said there were more than 500 million military weapons available on the world market and that in Australia, South Africa and the United States there are more security guards than there are soldiers in the military. Spending for private security now

amounts to more than 50 billion dollars. More than the police budget of every nation of the world and most military except the US and Russia.

While the military can treat some of the symptoms of this changed security environment, it is not well suited to deal with the root causes such as population growth, lack of economic development, or environmental degradation.

Therefore, security is increasingly derived from an aggregate of political, economic, cultural and military factors. The conflict in the Balkans is rooted in intractable cultural divisions that no amount of conventional military force can realistically hope to solve. You can put all of NATO into Bosnia and until you address the cultural and economic problems you will not be successful.

Today, "instability" constitutes the primary threat to security in all its dimensions. Instability anywhere affects everyone in a global economy. Moreover, with global communications and permeable borders, it can overcome nearly every effort to contain it. Our strategy of the future require multi-faceted engagement at all levels.

Throughout history, we have waged warfare using the same technologies and techniques that we used to create wealth. Agricultural societies fought with peasant armies. The Industrial Age brought about the mass production of weapons, tanks and airplanes. Massive armies were moved and supplied by vast networks of rail, sea, air and road transport.

The Information Age is making such industrial age concentrations lucrative targets. The Gulf War was but a crude preview of how precision, high-tech weapons are changing the dynamics of the battlefield. During the Gulf War, one F-117 sortie with laser guided bombs was able to destroy the same types of targets that required 1500 B-17 sorties in 1943, and 176 F-4 sorties in 1970. As a result, our historical reliance on mass decreasing as the precision and lethality of weapons increases exponentially. We must therefore recognize that the most critical parameter in future conflicts will be time. By skillfully using there non-lethal tools of the Information Age, we should be able to prevent conflict in most cases, and bring others to a speedy conclusion with minimal friendly casualities. This is very important because the Achilles heel of any deployment of US forces is the willingness of the US Congress to sustain overseas deployment of US forces. I would on. point to events in Somalia, Haiti and Bosnia to make the point.

By 2010, our information systems will be capable of transmitting and processing 1.5 trillion bits of information a minute. This represents an exponential increase over time. In World War I we put 4 thousand soldiers in a 10 km2 area and talked to them at a rate of 66words per minute. Today we put 24 soldiers in the same space and talk to them at a rate of 192K words per minute. Tomorrow we will reduce that number to 3 soldiers and give them 1.5 trillion bits of information. What this issue really boils down to is that there is a trade-off between order battle, readiness and modernization. During the cold war order of battle or force structure was important. Today modernization and readiness is more important. Large standing formations are an impediment to progress.

However these information and technology systems can be obtained by small as well as large nations. This means that in the future, a "David vs. Goliath" will characterize tomorrow's battlefield, the David of tomorrow has access to a veneer of technology that gives him more than a fighting chance to inflict serious casualties on US forces. This is especially true in the air defense area, where the commercial market is

flooded with relatively cheap, high quality, anti-aircraft weapons capable of shooting down a $70 million tactical aircraft.

In conclusion, let me say that the type of security landscape I am suggesting is manageable but in order to prosper we need to put a greater focus on harnessing the *intellectual* capital of our laboratories and the bright young people in this global village. We can not continue to rely on just kinetic military options. If we do, we do ourselves and the people we are paid to protect a great disservice. Thank you and thank you for the work you have done.

The U.S. Department of Defense
Joint Non-Lethal Weapons Program

Pax Custimus

Department of Defense

Non-Lethal Weapons

Vita Custimus

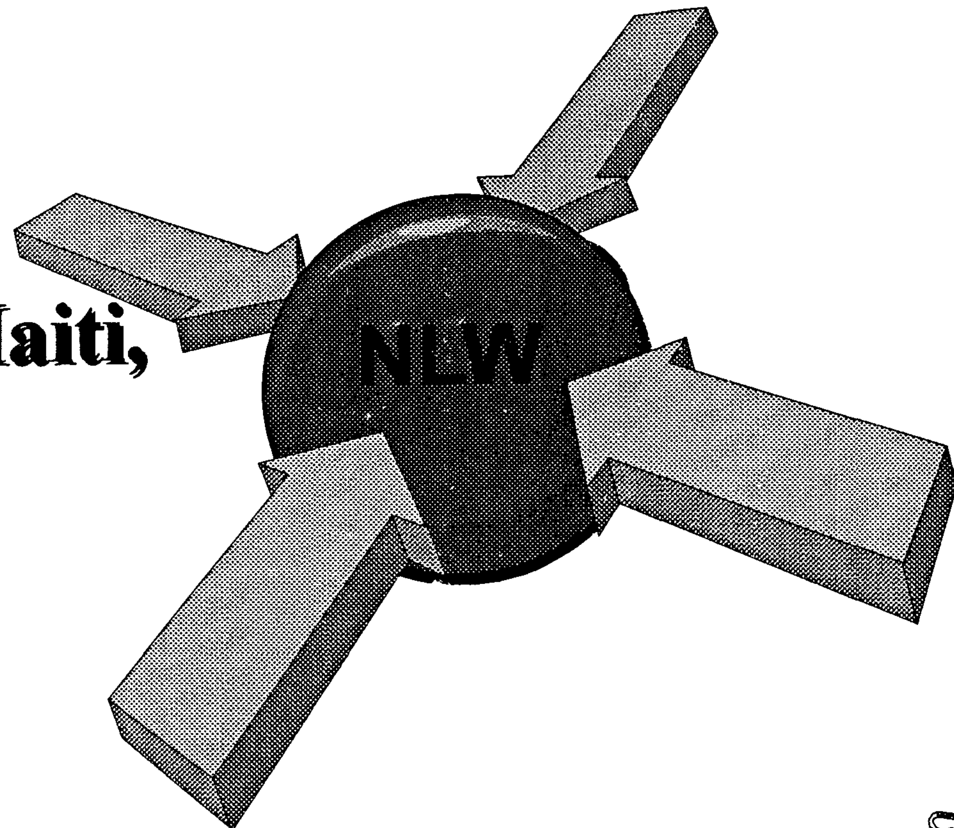
NON-LETHAL DEFENSE CONFERENCE III
25 - 26 FEB 1998

PURPOSE

To provide an overview of the U.S. Department of Defense's Joint Non-Lethal Weapons Program

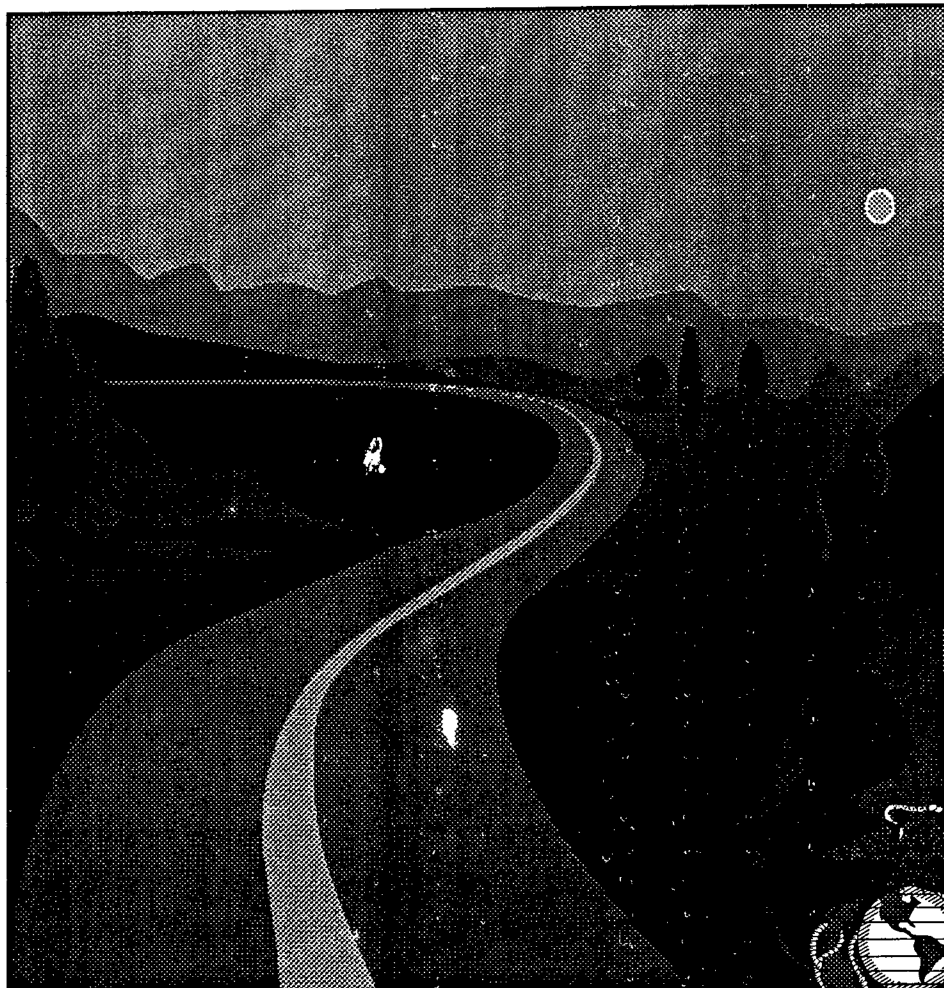
Where We Came From

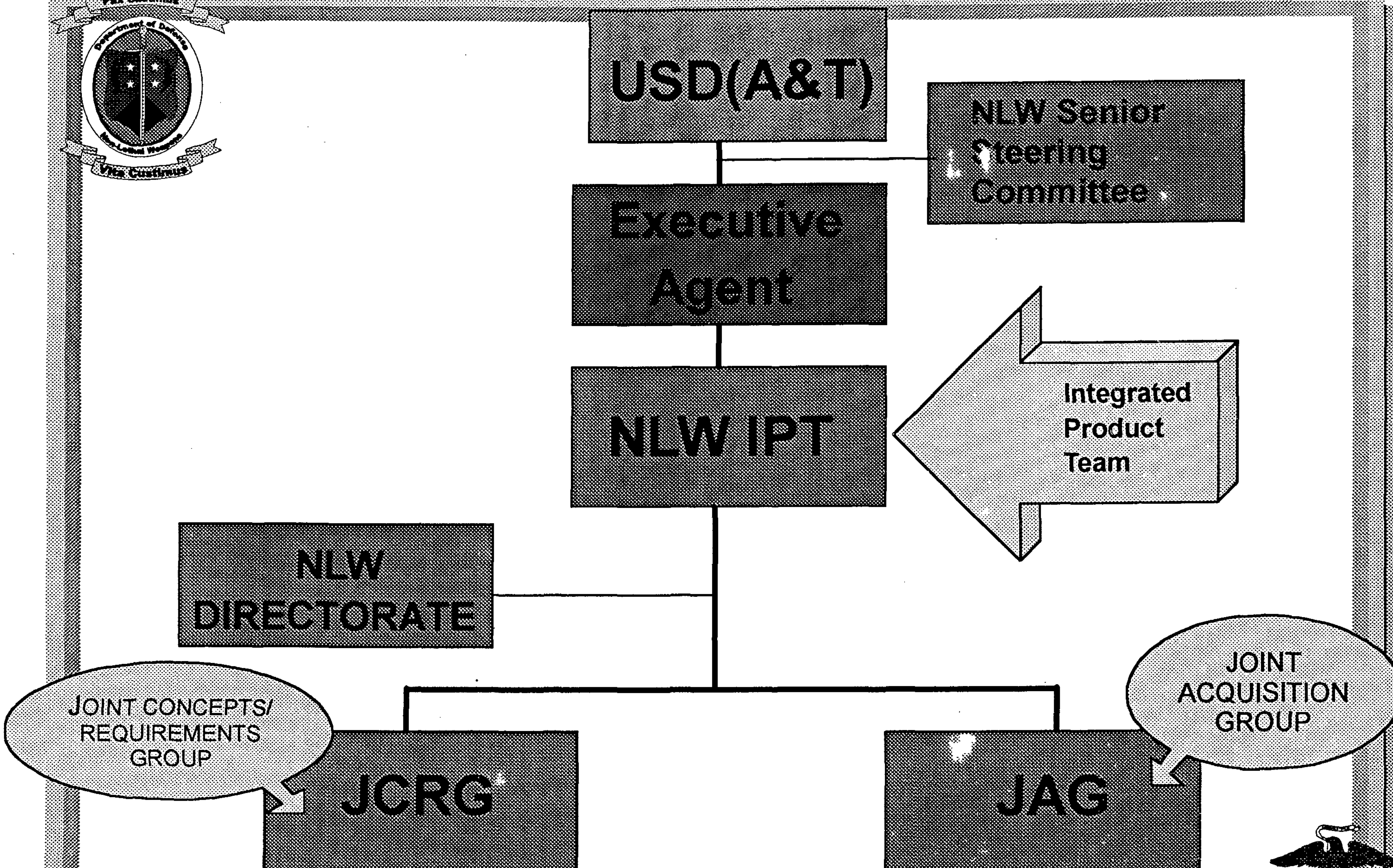
- 1970/80's many disjointed efforts
- 1990's: Somalia, Haiti, Bosnia
- General Zinni
- Congress & OSD



Where We Are Headed

- A joint, coordinated and focused effort
- Oriented toward more rapid fielding
- Blend of low tech, near-term with high tech, long range

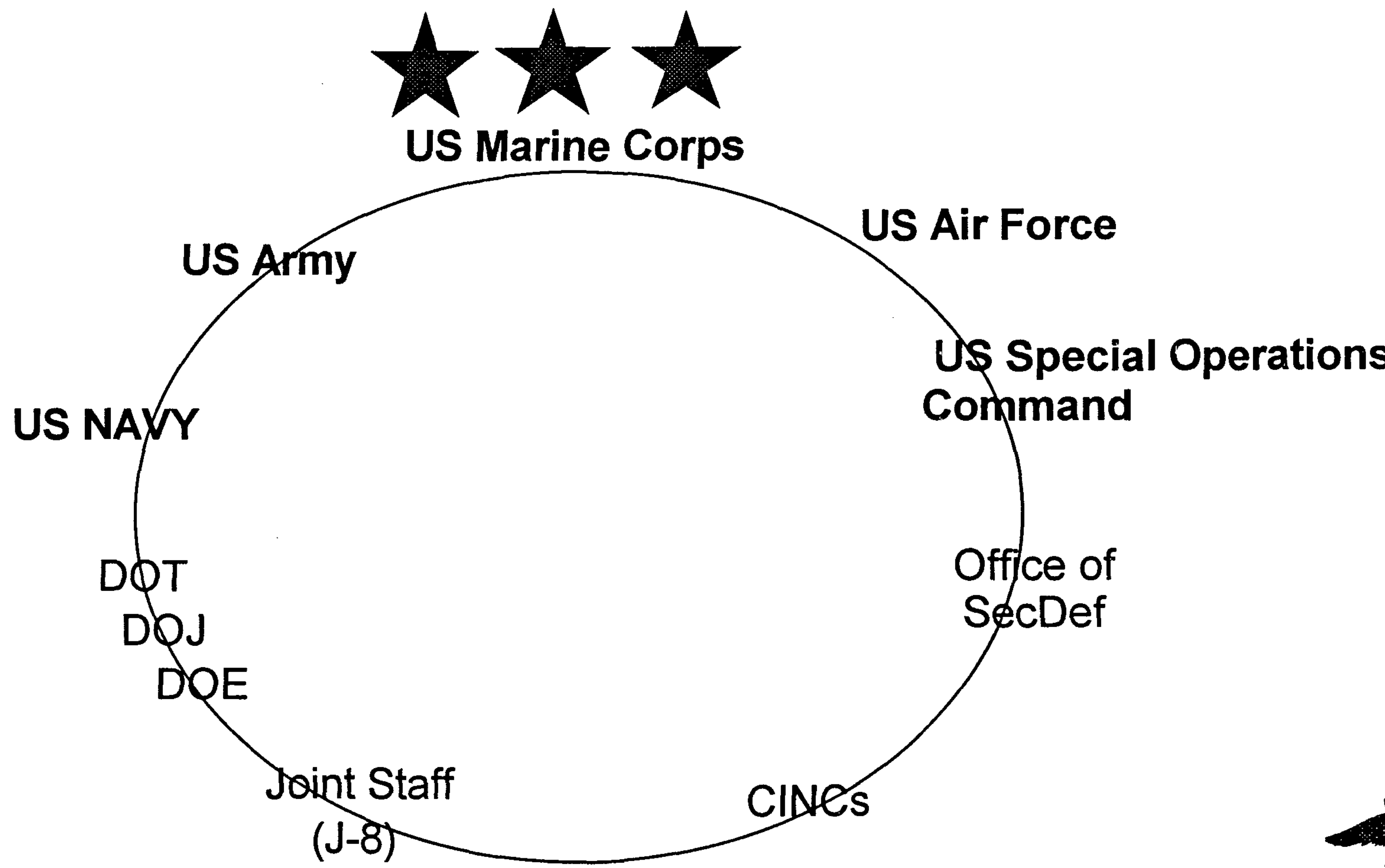




NLW Management Structure

Director, Joint Non-Lethal Weapons

Integrated Product Team (IPT)



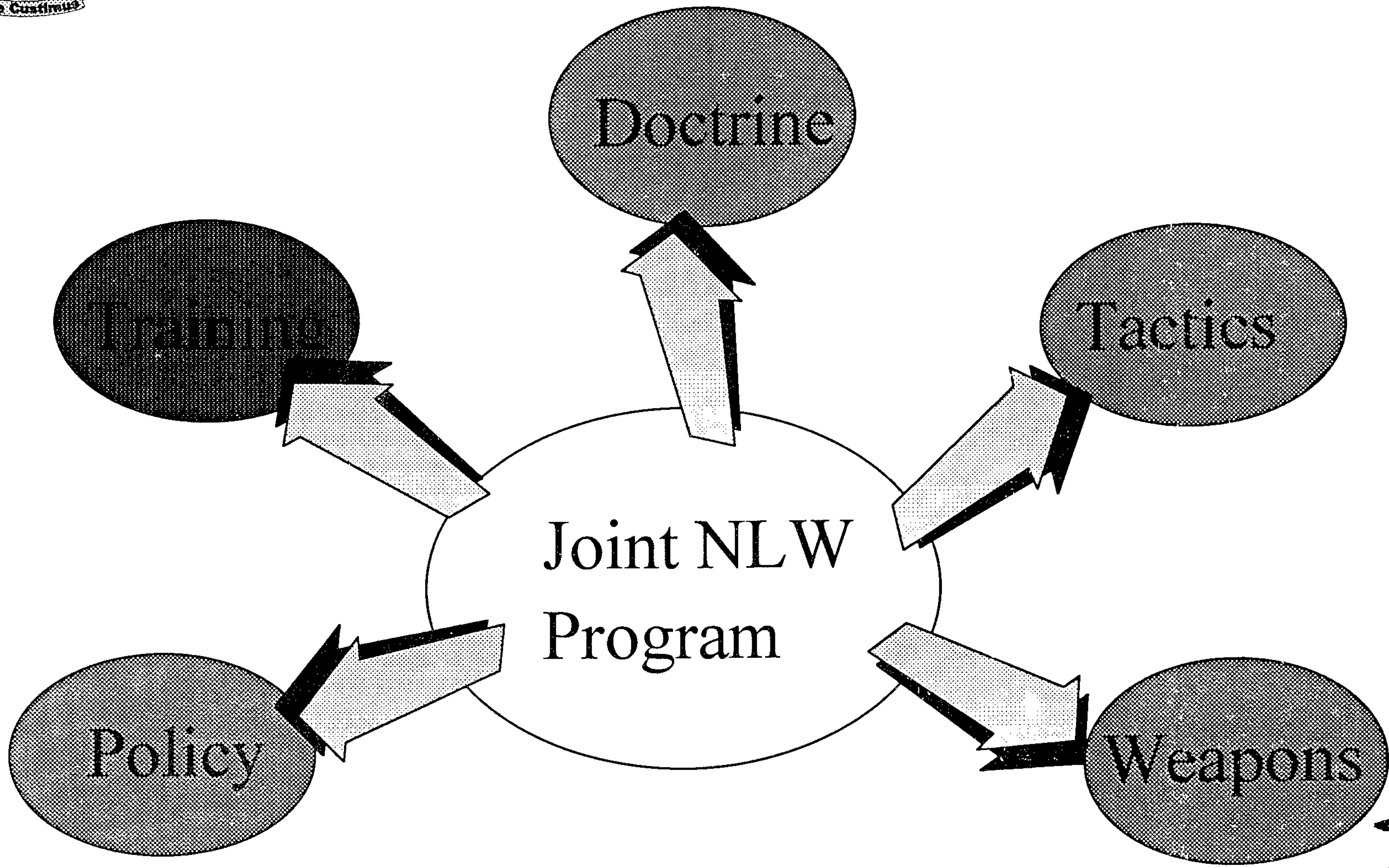
Voting Members in **bold**

Director, Joint Non-Lethal Weapons

Directorate Responsibilities

- Perform day-to-day activities for EA
- Manage joint funds
- Liaison w/DoD, OGAs, and foreign governments
- Publish Master Plan
- Assist in budget development
- Monitor execution of NLW Program
- Monitor other Service programs
- Promote exchange among Services

The NLW "Environment"



The Joint NLW Concept

"Guiding Principles"

- Leverage High Technology
- Enhance Operations
- Augment Deadly (Lethal) Force
- Provide Rheostatic Capability
- Focus on Tactical Applications
- Expeditionary
- Acceptable
- Reversible Effects

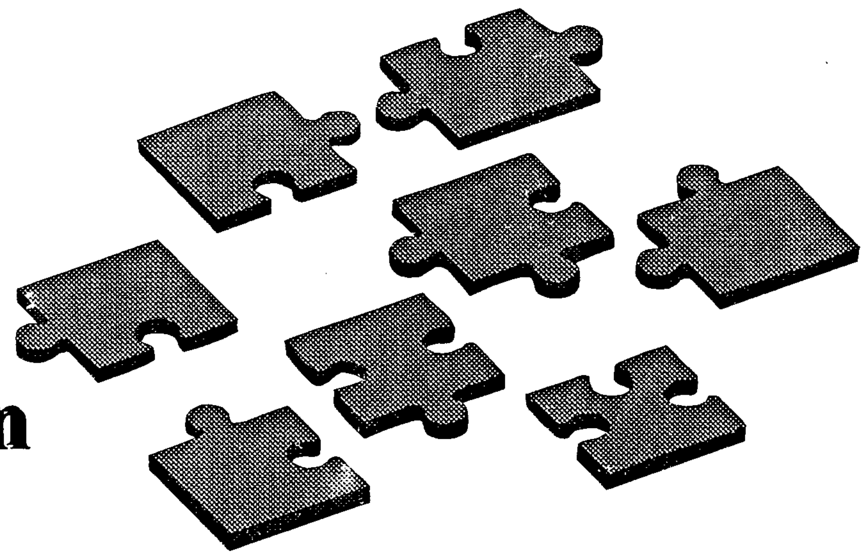
The Joint NLW Concept

"Core Capabilities"

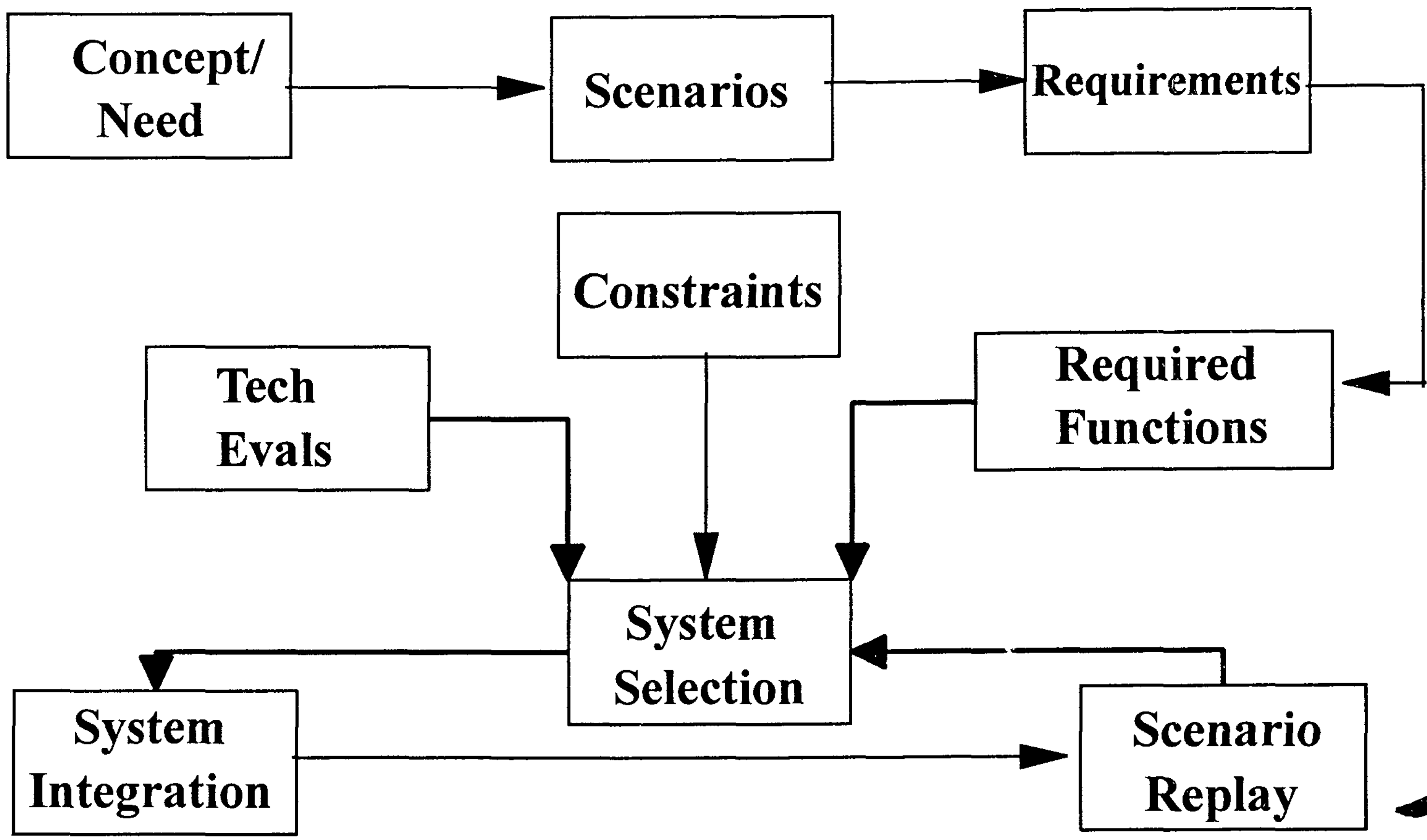
- **Counter-Personnel**
  - Crowd Control
  - Incapacitate Individuals
  - Deny Access
  - Clear Facilities/Structures
- **Counter-Materiel**
  - Area Denial (land, sea and/or air space)
  - Disable/Neutralize Equipment or Facilities

Non-Lethal Weapons Research & Development

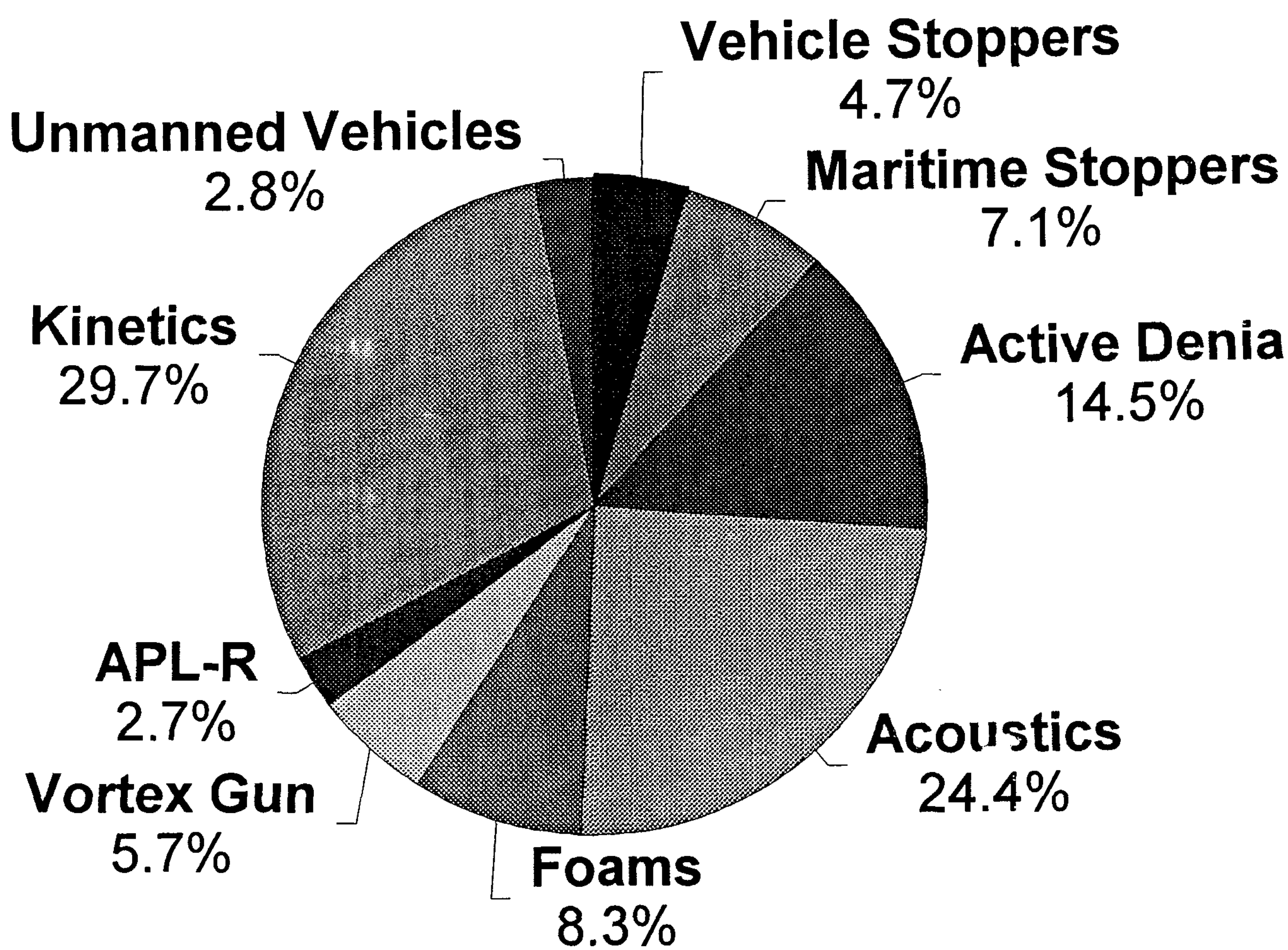
- Funded Projects
- Experimentation
- Modeling/Simulation
- Tech Investment



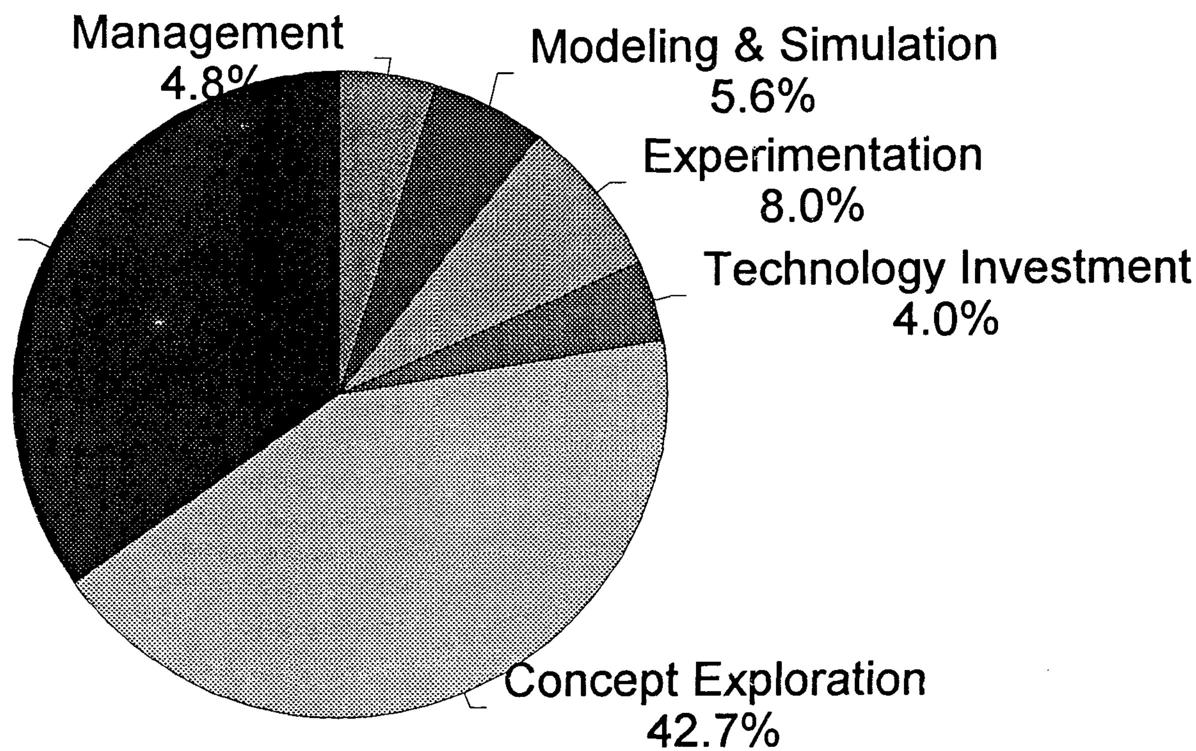
A Concept-Based Systems Approach



Technology Breakout



Year 2000 Funding Overview



Director, Joint Non-Lethal Weapons

Rules of Engagement - NLWs

"Emerging Concepts"

- RCAs can not be addressed separately
- No such thing as 100% non-lethality
- NLWs always backed by lethal force
- Availability does not limit commander
- Need to define term "measured response"
- Force protection primary consideration

BOSNIA LESSONS

- ✓ Level of knowledge in theater
- ✓ NL Policy/ROE
- ✓ Highly charged, political environment
- ✓ Available munitions/Other NL options
- ✓ Tactical employment concepts
- ✓ Sticky foam

Joint Services NLW Training

- Builds on past experience
- Recognizes individual Services' training requirements
- Comprehensive NL training package for resident trainerand user course, and mobile training capability
- Training includes tactics, communications, crowd dynamics, weapons/munitions, and rules of engagement

Other NLW Activities

- DOD NLW Web Site
- DOD NLW Database
- Human Effects Advisory Board
- Co-sponsor NLWD II Conference (2/98)
- Foreign Information Exchange

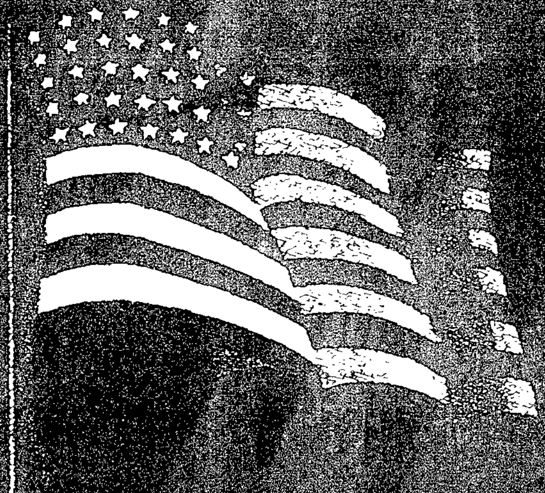
Summary

NLW Team

Focus on Soldier, Sailor, Marine, Airman

Form, Structure and Direction

QUESTIONS ?



Non Lethal Materiel Program

Presented by

Hildi S. Libby

Systems Manager

AMC Non Lethal Materiel Program

FY 98/99
Service Program List

1. NL Crowd Dispersal (M203)
2. Acoustic Bio-Effects
3. MCCM (NL Claymore)
4. Stoppers
   a. Ground
   b. Maritime
5. Speed Bump (Net)
6. Area Denial Technology
7. 66mm Vehicle Launched Payload
8. UAV NL Payloads
9. Bounding NL Munition
10. Canister Launched Area Denial System (CLADS)
11. Foam Applications
12. Acoustic Generators
13. Vortex Ring Gun
14. Underbarrel Tactical Payload Delivery System

The Goals

FY95 FY00 FY 05 FY10

Short Term

Put a "family" of multi-purpose, easily trained, and inexpensive non-lethal tools which can be employed from existing weapons platforms into the hands of the soldiers in order to satisfy immediate user requirements.

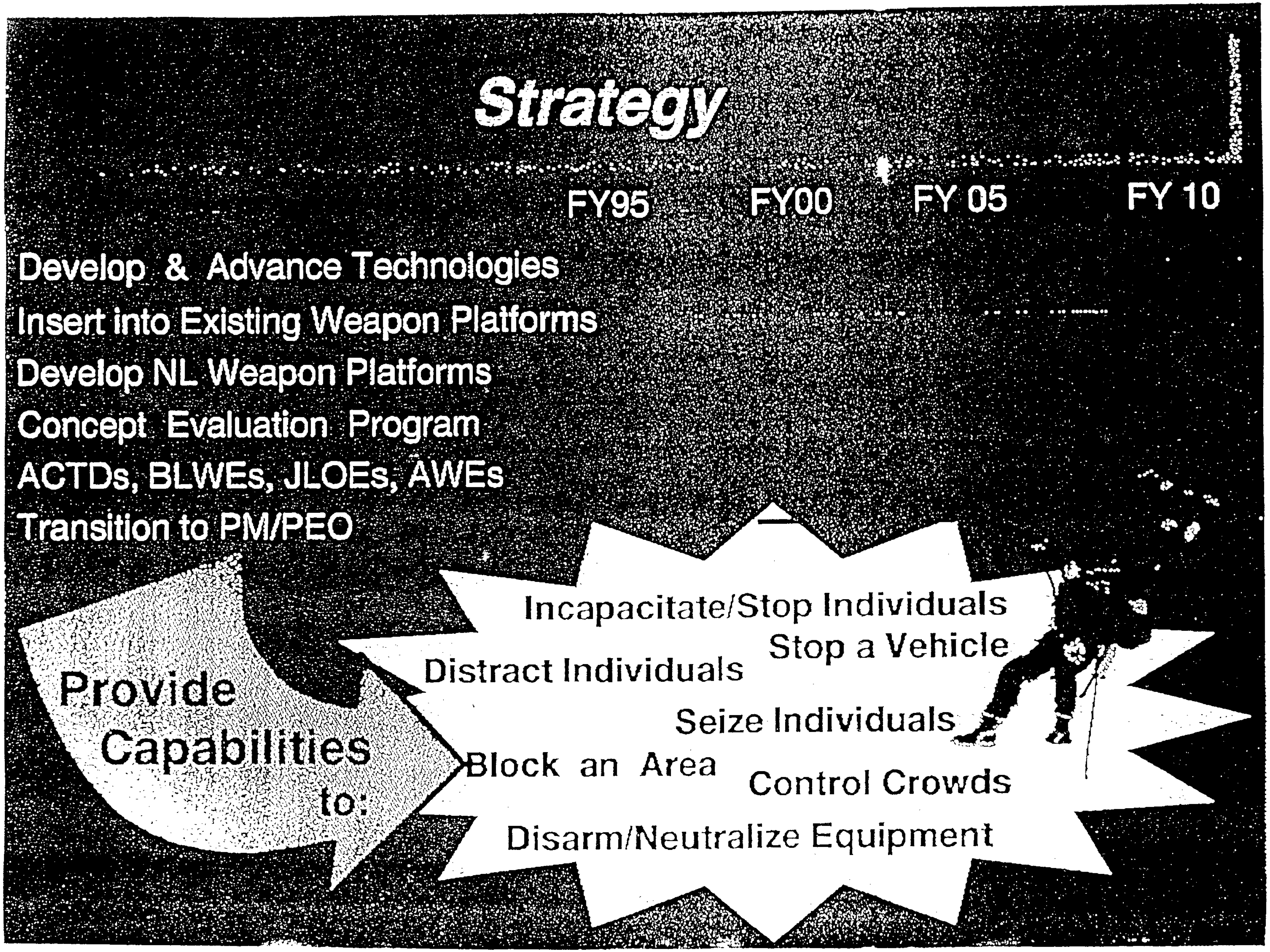
Long Term

Improve on solutions to immediate requirements. Anticipate and provide solutions to future user requirements.

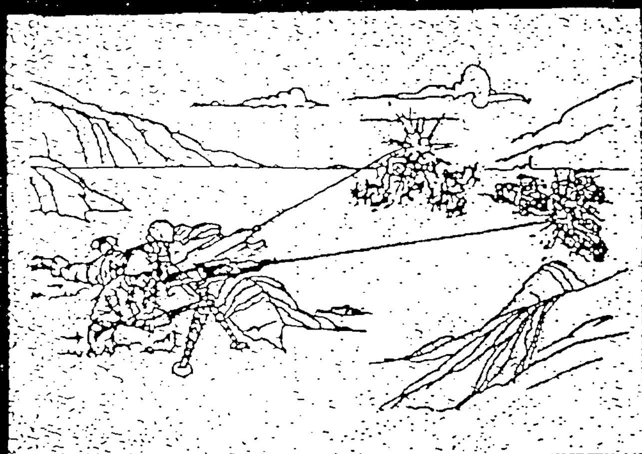
Mission Need Statements

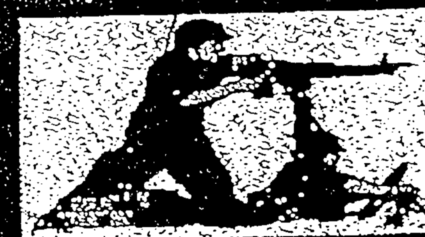
The US Marine Corps and Army have Approved Mission Need Statements

- Areas of Commonality include:
  - Enhancing Operational Capability
    - Conduct Operations across the Range of Military Operations
      - Missions include: Cordon and Search, Humanitarian Assistance, Peace Enforcement, Peace Keeping
        - Systems that provide flexible means of response


Strategy
FY95
FY00
FY 05
FY 10
Develop & Advance Technologies
Insert into Existing Weapon Platforms
Develop NL Weapon Platforms
Concept Evaluation Program
ACTDs, BLWEs, JLOEs, AWEs
Transition to PM/PEO
Provide Capabilities to:
Incapacitate/Stop Individuals
Stop a Vehicle
Distract Individuals
Seize Individuals
Block an Area
Control Crowds
Disarm/Neutralize Equipment

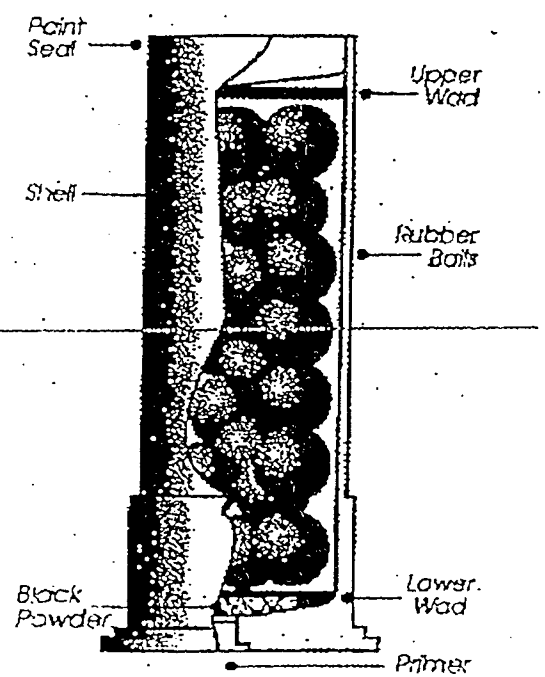
Capability/Technology Roadmap





	Incapacitate/Stop Individual(s)	Distract Individual(s)	Seize Individuals	Stop a Vehicle	Block an area	Control Crowds	Disarm/Neutralize Equipment
Acoustics	✓	✓			✓	✓	
Kinetics	✓	✓				✓	
Entanglements	✓		✓	✓	✓		
VehicleStoppers				✓			✓
Riot Control Agents	✓	✓	✓		✓	✓	

NL Crowd Dispersal (M203)



Category: Anti-Personnel

Concept of Operation: Crowd Control Incapacitate Personnel

Technologies: Blunt Impact Trauma

Program Objectives: To Type Classify a 40mm Non-Lethal Crowd Dispersal round for the M203 Grenade Launcher

Acoustic Bio-Effects

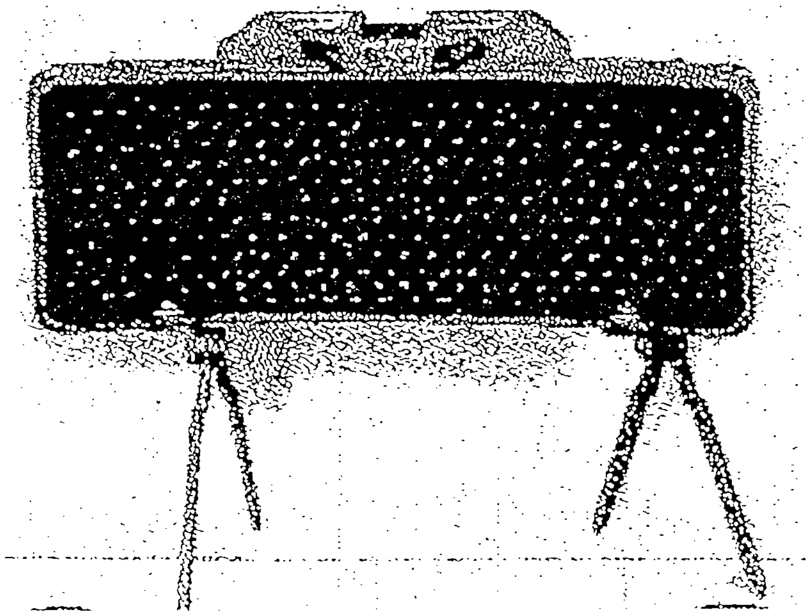
Category: Acoustics

Concept of Operation: Crew-served or vehicle mounted weapon to provide crowd control and/or area denial.

Technologies: Resonance, mechanical pressure wave generation, impedance matching and target coupling

Program Objectives: Provide the warfighter with a weapon capable of delivering incapacitating effects, from non-lethal to lethal.

MCCM (NL Claymore)



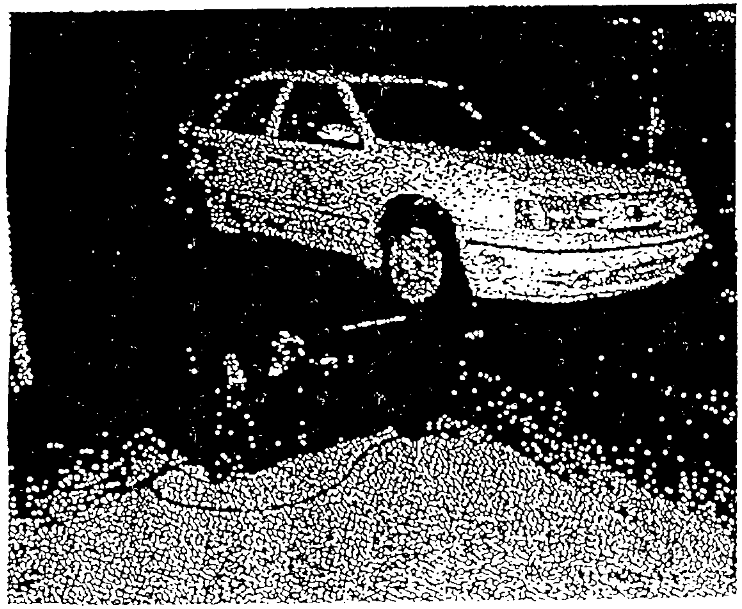
Category: Kinetics, Pre-emplaced.

Concept of Operation: Crowd control and vehicle self protection
- NL version of M18A1 Claymore

Technologies: Propelling charge with rubber balls and Flash-bang.

Program Objectives: Transition design of M18A1 APERS into a device to produce sting effect at 5-15 meters with flash and bang.

Stoppers (Ground)



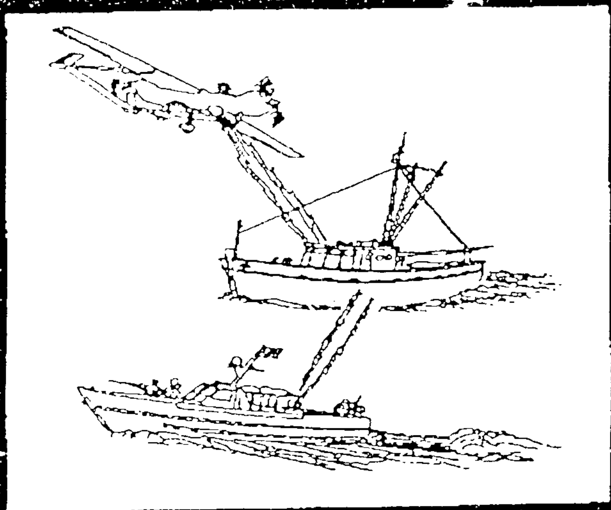
Category: Ground Vehicle Stopper

Concept of Operation: Stop a vehicle engine by disabling electronic components

Technologies: Swept frequency microwave transmitter, direct injection device (high voltage)

Program Objectives: Develop a lightweight, compact device capable of stopping both military and commercial engines.

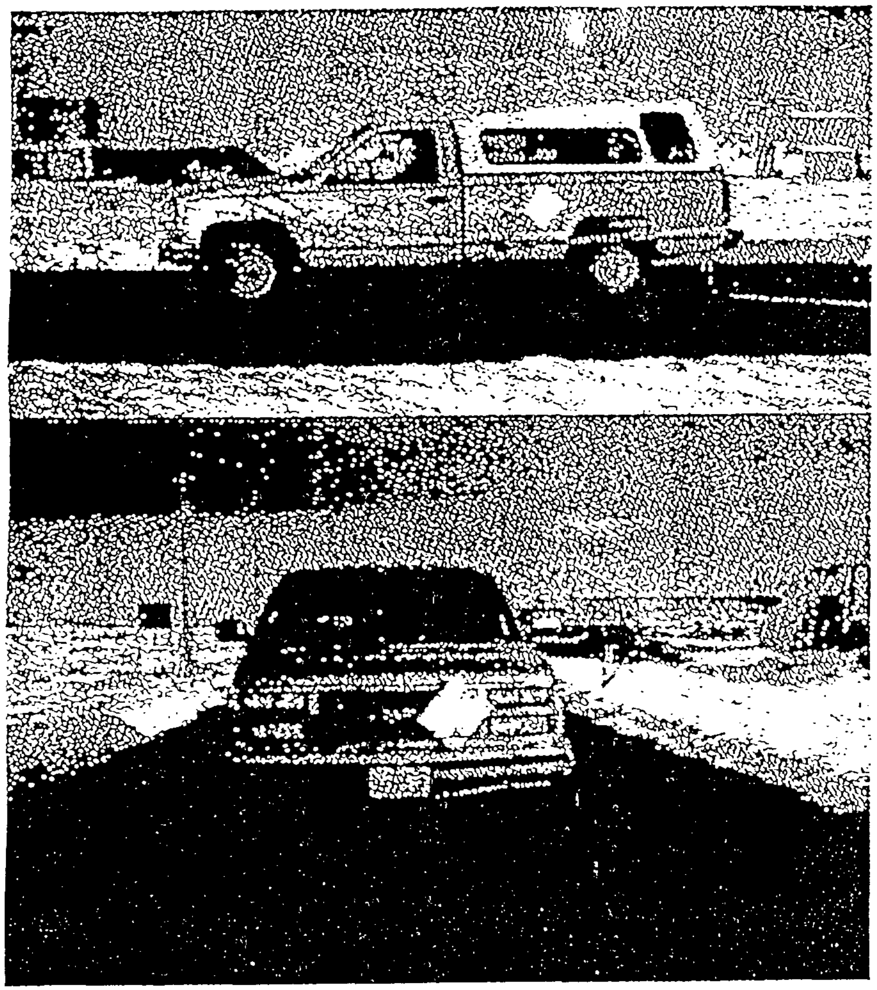
Maritime Vessel Stoppers



- Objective: To develop a device that will disable small inboard diesel powered surface vessels without injury to the occupants.
- Approach:
  - Target vulnerabilities will be assessed
  - Various anti-material/ anti-personnel technologies will be investigated to identify the optimum solution
- U. S. Navy is the lead investigator

Director, Joint Non-Lethal Weapons

Speed Bump (Net)



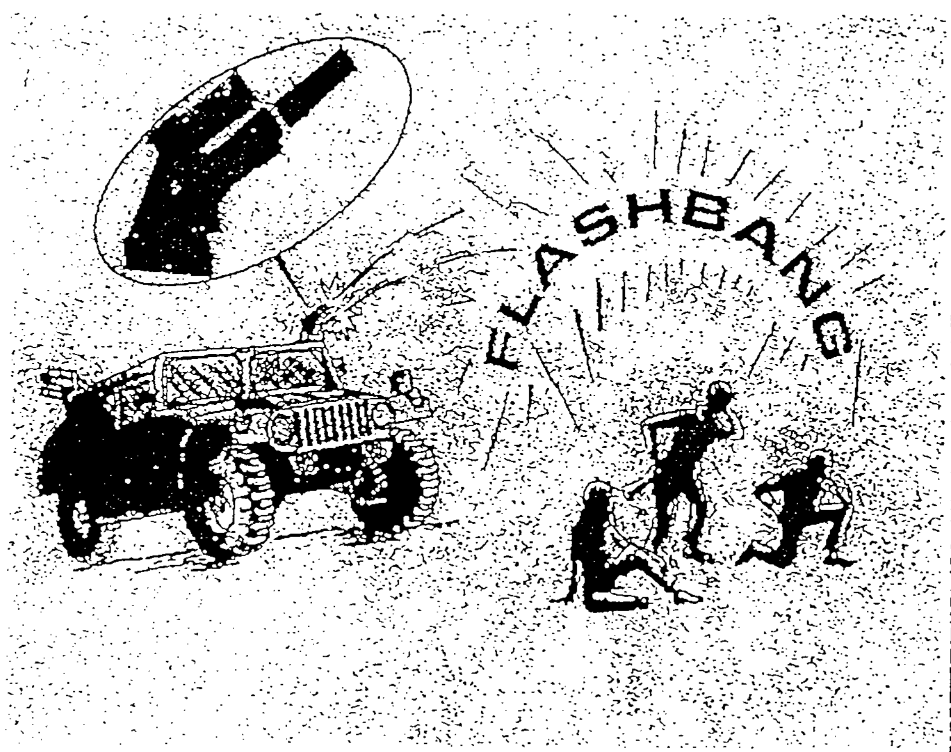
Category: Vehicle Stopper

Concept of Operation: Pre-emplaced at key vehicle entry points without impeding flow of traffic. Command-activated to capture suspect vehicle without serious injury to occupants.

Technologies: Pneumatic telescoping poles, vinyl webbed arresting net, disc braking system.

Program Objectives: To demonstrate a Proof-of-principle pre-emplaced NL vehicle immobilizing "Speedbump" system. The intent is to stop a 5,100 lb vehicle traveling at 40 - 60 mph within 200 ft, without serious injury to the vehicle occupants.

66mm Vehicle Launched Payload



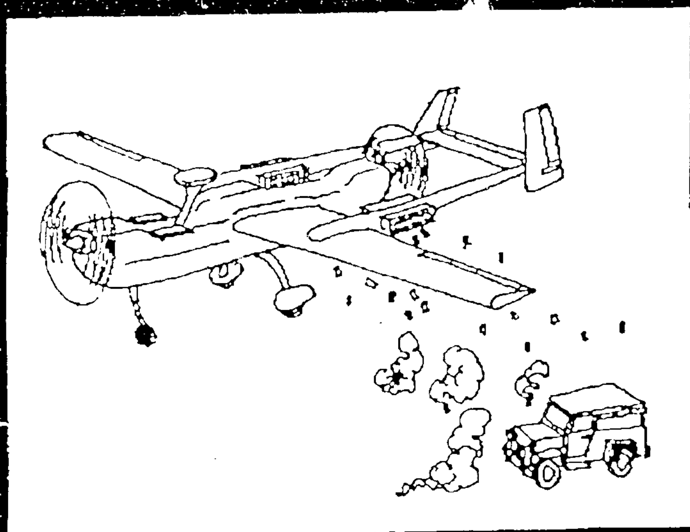
Category: 66mm Vehicle Launched NL Munition

Concept of Operation: System employed at standoff from vehicle to deter riotous crowds

Technologies: Kinetics, Pyrotechnics (Whistles, flash/bang).

Program Objectives: Develop NL flashbang payload for 66mm Vehicle Launched system for crowd control purposes.

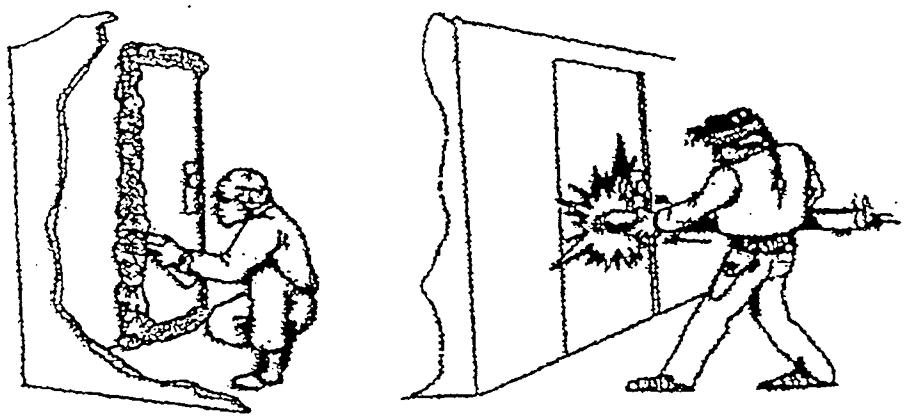
UAV NL Payloads



- Objective: To develop a non-lethal payload dispensing capability for tactical UAVs
- Approach:
  - Develop universal dispenser with UAV specific integration kits
  - Package and demonstrate various non-lethal payloads (e.g. malordorants, stingballs)
- U. S. Navy is the lead investigator

Director, Joint Non-Lethal Weapons

Foam Applications



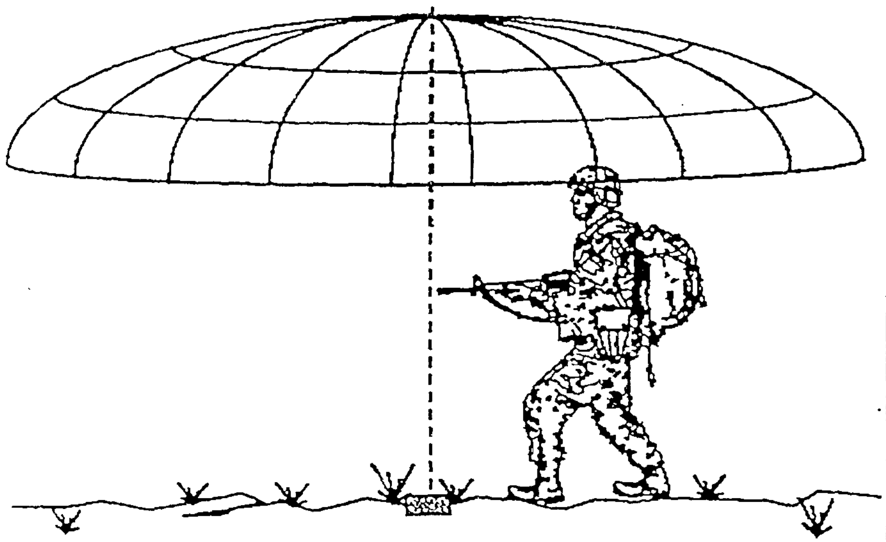
Category: Rigid Foam and Epoxies

Concept of Operation: Rigid foams for area denial and quick seal of doors and window. Also as an anti-materiel agent for small arms and other equipment.

Technologies: Polyurethanes, epoxies, adhesives, dispenser \packaging.

Program Objectives: To formulate/design a fast curing rigid foam and dispensing system

Bounding NL Munition



M139 VOLCANO Dispensed Net
&
M16A2 Hand Emplaced "Bo ıncing Betty"

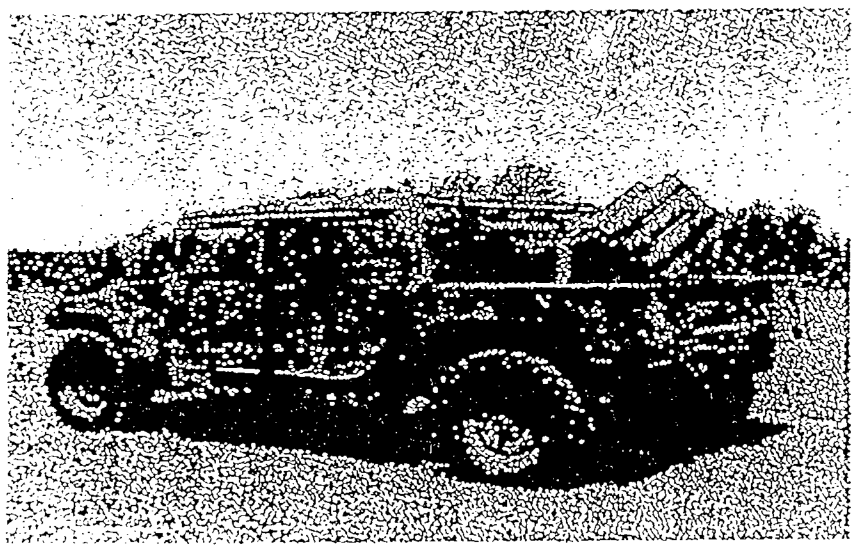
Category: Entanglements, Site Security/ Perimeter Defense.

Concept of Operation: Item functions similar to tactical bounding APERS mine (Volcano M16A2) but with entanglement payload (add delay to APL alternatives).

Technologies: Rapid, reliable activation (IR sensor, trip wire) for high reliability capture. Potential immobilization enhancers - adhesive (sticky) net and electric (sting) net.

Program Objectives: To demonstrate the deployment of an entanglement net from a tactical bounding munition.

Canister Launched Area Denial System (CLADS)



Category: **Entanglement (AP/AM)**

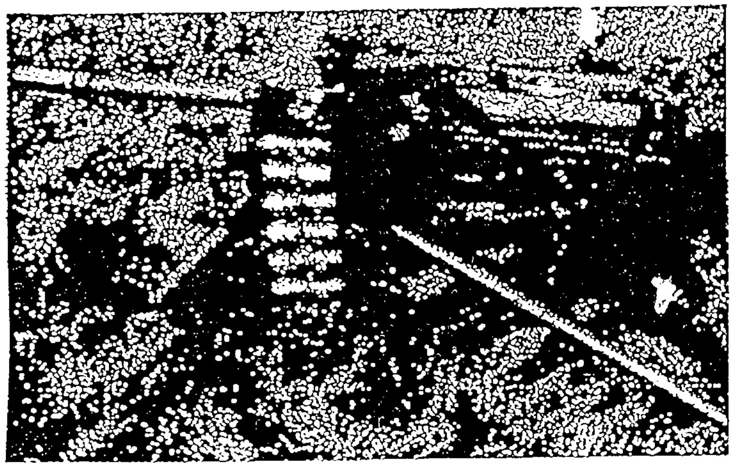
Concept of Operation: Rapidly deploy Non Lethal (NL) payload barriers from the Volcano Mine Dispenser system mounted on a HMMWV, utilizing a 20 canister launcher rack.

Technologies:

- Payload selection (various)
- Modular Payload
- Ignition system to launch payload

Program Objectives: Demonstrate and validate the dispensing of NL payloads (concertina, bounding net, malodorous, etc.) from a Volcano system utilizing a 20 canister rack, mounted on a HMMWV.

Vortex Ring Gun



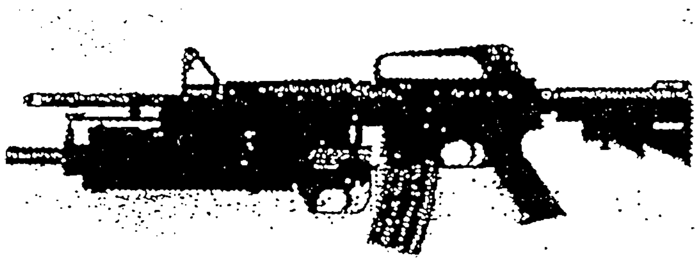
Category: Vortex Ring Gun (VRG)

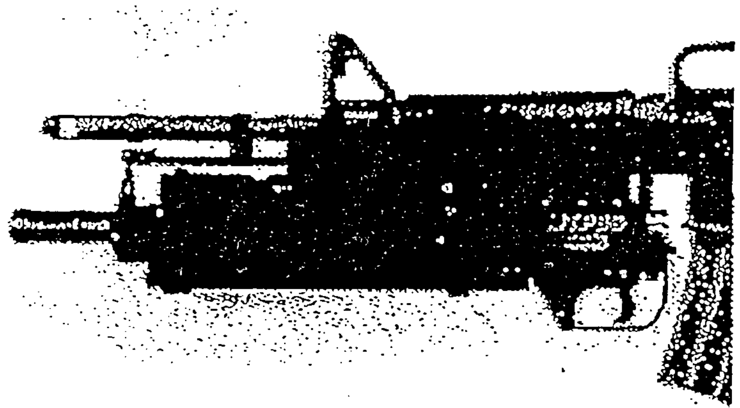
Concept of Operation: Apply vortex ring gas impulses with flash, concussion, and non lethal agents and/or markers to personnel at approximate human body resonance frequencies to provide the user with area denial and crowd control capability.

Technologies: Vortex ring formation and propagation, entrainment of non lethal and marker agents in vortices, telescoping blank MK-19 40mm round.

Program Objectives: Provide the user with a retrofit kit for the MK19-3 automatic 40 mm grenade launcher to enable quick changes between lethal and non lethal operations employing blank cartridges, a supersonic nozzle and liquid agent reservoir.

Underbarrel Tactical Payload Delivery System





Category: Kinetics - Point and Area Target

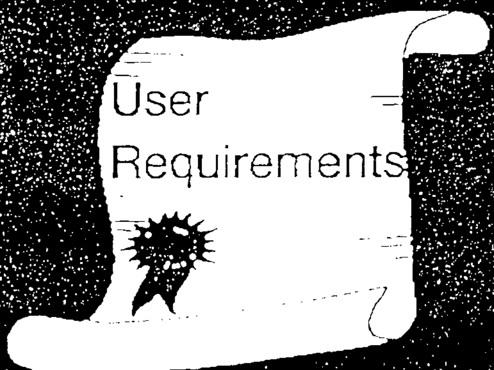
Concept of Operation: Neutralize selected targets and areas at a distance of 30-100 meters with a modular, secondary NL multi-shot armament system. Near instantaneous change over to M16A2/M4's lethal fire.

Technologies:
- Pneumatic (compressed-air propulsion)
- Various payloads (impact, OC, dye)

Program Objectives: To integrate an under-barrel non lethal (tactical paint-ball type) weapon system on the M16A2/M4 for Crowd Dispersal, Point Target, and MOUT.

Non-Lethal Materiel Program Conclusions

Specific Requirements critical to "drive" materiel development and acquisition.



Must be able to control civilians/noncombatants in order to succeed on the missions of tomorrow

The test program was a success, demonstrating that a liquid slug does retain its integrity and that performance is essentially as calculated based on the original theoretical model. Tile and clay targets presented in Figure 2 were shot with the Proof of Principle Liquid Projectile Weapon at ranges between 2 and 12 meters (6.6 to 39.4 feet).

The ballistic pendulum data shows energy delivered to the target decreases monotonically with distance. Using measured slug weight in the pendulum, we solved for terminal velocity. Our calculations showed the slug had lost some mass, but very little velocity. We postulate that as the slug advances through air, its leading edge is peeled off and breaks into droplets which would decelerate greatly before contacting the target or not reach it at all, but the majority remains in a long cylindrical shape, retaining its kinetic energy. A slug weighing 0.33 lb. traveling at 300 ft/sec. carries about the same amount of energy as a 0.45 caliber bullet. This has been shown to have a painful impact.

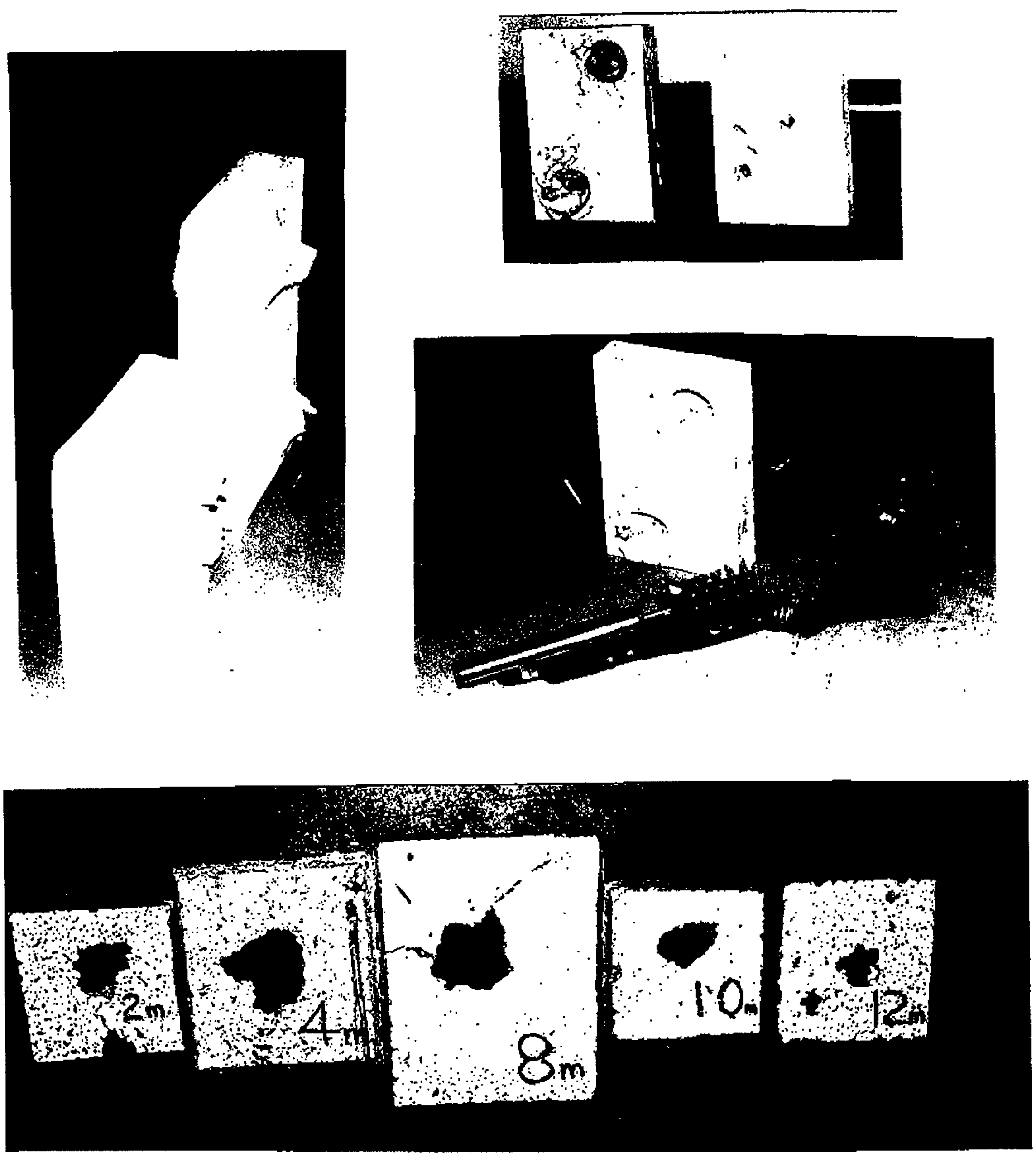


Figure 2. Tile and Clay Targets Shot at Ranged to 40 Feet.

3.0 RESEARCH PROGRAM

UTD has performed engineering, constructed a Proof of Principle mock up, and conducted physical experiments. UTD's IR&D efforts were targeted at answering the fundamental issues of the Liquid Projectile Weapon's feasibility. The key issue was: will the liquid slug transport sufficient energy to a target through a range of at least 40 feet? UTD commenced with a complete theoretical description of significant relationships relating to fluid mechanics including nozzle velocity and discharge rate versus pressure, flow conditions and its effect on the projectile form, range, and velocity.

After conducting engineering analysis, a laboratory test bed was set up. The laboratory apparatus included a proof of principle Liquid Projectile Weapon, shown in Figure 1, consisting of a main cylinder, piston and nozzle, nitrogen gas supply tanks, and valving, capable of launching a slug of liquid at stagnation pressures up to 1000 psi through nozzles ranging in size from 0.375" to 0.75" diameter; a ballistic pendulum capable of measuring the energy and weight of the liquid slug at ranges to 40 feet; and wallboard and clay targets which showed the pattern of the liquid impact.

UTD conducted several hundred test firings to characterize the weapon's performance. UTD used different liquids, internal components, and stagnation pressures. Specific gravity and viscosity had a dramatic effect on how well the liquid slug "held together" after launching. Water, which is better from a clean up standpoint, would atomize at a range of 50 feet or so, and lose it's "punch." Water would launch well into the turbulent range ($Re > 10^6$). As expected, maple syrup, which has a viscocity several thousand times greater than water, would launch well into the laminar flow range and held together better at long distances. The specific gravity of maple syrup is 1.3 to 1.5 times fresh water. Suprisingly, we found little difference at ranges under 20 feet.

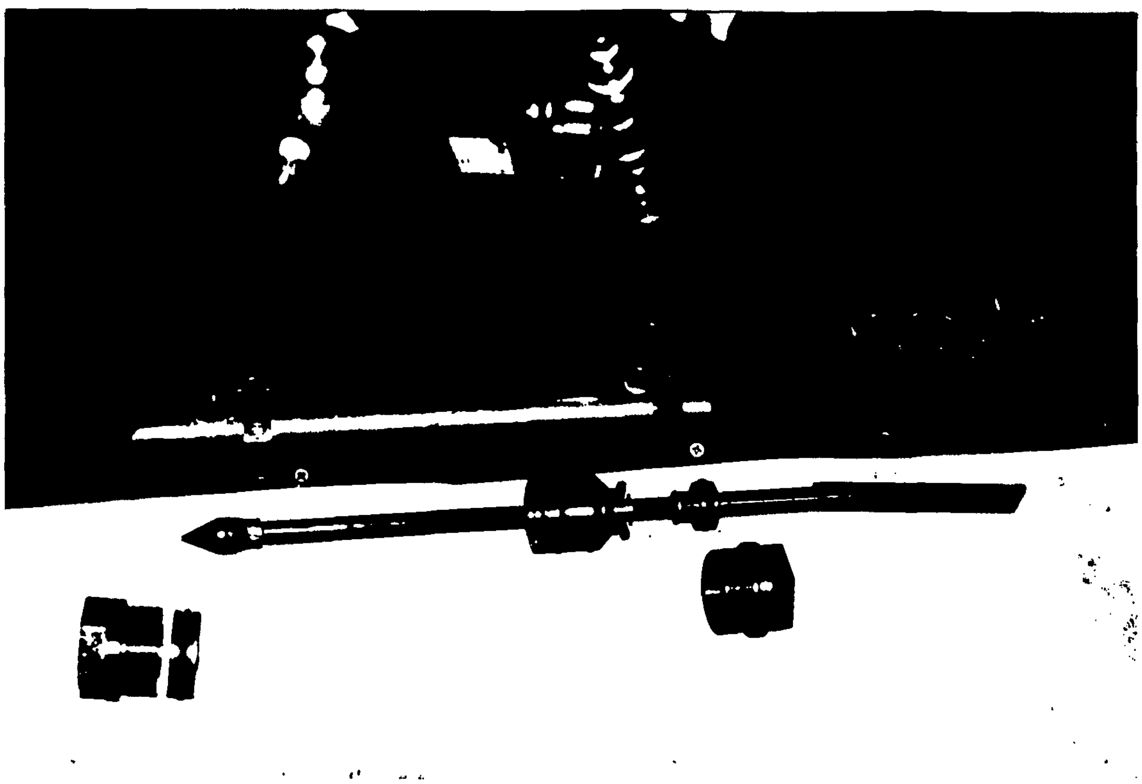


Figure 1. Liquid Projectile Weapon Bench Test Set Up.

For Delivery at the National Defense Industrial Association (NDIA) Non-Lethal Defense III Conference
February 26, 1998

by

JAMES B. SEATON III*
Director for Defense Policy
National Security Council

Nonlethals and the 21st Century Art of War

In recent years the simple, yet profound, writings of the Chinese philosopher-General Sun Tzu have gained increasing popularity among strategic thinkers, military officers, academics and business executives. Sun Tzu's *The Art of War* is in many respects a warfighting manual. In another more enduring sense, however, it is a primer to guide strategic thinking and planning. As we talk about nonlethal weapons and technologies on the eve of the 21st century, it is instructive to reflect on some ideas articulated by Sun Tzu circa 400 B.C. Allow me to quote from his third chapter, entitled "Offensive Strategy:"

Generally in war the best policy is to take a state intact; to ruin it is inferior to this. [and]

To capture the enemy's army is better than to destroy it; to take intact a battalion, a company or a five-man squad is better than to destroy them.

I cite these ancient Chinese passages to help frame some of my comments and to provide context for thinking about nonlethal technologies.

My remarks are not intended to reflect the views of the White House or the NSC staff. That said, I hope my comments will help broaden the larger discussion on nonlethal weapons and technologies within our national security strategic framework.

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* A Marine Corps officer, Jim Seaton has served at the White House as Director for Defense Policy on the National Security Council staff since 1994. He has been a Council on Foreign Relations International Affairs Fellow, taught political science at the U.S. Naval Academy, served in Grenada and Lebanon in 1983-84 and has written on American civil-military relations, low-intensity conflict and conflict intervention in the Middle East. He has an M.A. in political science from Duke University.

Policymaking requires options -- diplomatic, economic, military, and informational. Without options, or choices, policymakers are extremely limited in their ability to influence outcomes, to shape policy to best represent or advance American interests.

National security objectives frequently demand that a country simultaneously prepare for a variety of challenging political-military situations, for rarely does a country face a one-dimensional security *threat*. If threats or challenges are similar, or reasonably similar, decisionmaking is simplified. Being ready may mean having a trained military and a transportation network suitably developed to counter invasion from opposite sides of the country -- the dilemma confronting Germany in earlier times. Or, better yet, being ready may mean focusing a country's efforts largely on just one border and one opponent -- the current situation on the Korean peninsula. Though that opponent may pose varied types and levels of threats -- from clandestine intervention to ballistic missiles -- it still permits policymakers to focus primarily on one potential adversary.

In many cases, however, a country preparing to counter different threats may actually have to train, equip and plan for different types of war -- the situation during much of the Cold War. For example, the Containment Doctrine presupposed that U.S. instruments of national power must defeat Communism and its ideological adherents in all "threat" forms -- from strategic nuclear threats, to continental threats, to major naval threats, to uprisings or Third World "Wars of National Liberation."

In the first two examples, the policymaking focus was limited to a singular threat or, in the German case, two very similar threats. In the third instance, the Cold War, policymakers confronted multiform situations requiring the United States to plan for different types of war. All three examples illustrate threat-based strategies.

Our interests, at home and abroad, force U.S. policymakers to confront varied national security challenges. Only a few of these require traditional warfighting options. Most require military forces in combination with other national, governmental and even nongovernmental agencies to rollback not some well-defined enemy, but a host of threats or security challenges that assume new and inherently dangerous dimensions. Some of these directly endanger the U.S. or our immediate interests; others generate instability that ultimately affects close allies; and still others combine to create circumstances of chaos and disintegration that demand U.S. leadership and involvement.

Contemporary conflict is often ambiguous, with unclear distinctions between the various parties to conflict, and between combatants and noncombatants; and it is less ideological and industrially-based than was the case in many past conflicts. In some cases it appears irrational -- in both causes and methods employed -- to traditional western conceptions of warfare (which may also support the validity and relevancy of understanding Sun Tzu). Regardless of its form and substance, conflict has in a great many, but not all, cases evolved from large-scale force-on-force formations between well-defined military enemies into something more nebulous and unpredictable. Conflict increasingly involves non-state actors fighting (in some form or other) states or other non-state actors in pursuit of various interests, and conflict is typically more societally-oriented than state- or military-oriented.

To further muddy the national security picture is the breakdown of borders - geographical and otherwise. Increasing global interdependence has made nations more vulnerable to growing transnational developments and threats. Diseases, refugees, narcotics, international crime syndicates, information, and weapons of mass destruction cross geographical borders unhindered.

Some of these threats are reaching a new critical mass as they go global. We witness increasing links between terrorism, narcotics, counterfeiting, weapons-grade plutonium smuggling, nerve gas attackers, and so on. Groups that previously specialized in only one activity in one region are now intermixing and engaging in many activities on a global scale.

The world is an unsettled place with expansive security concerns -- concerns driven by potential military threats, by the decreasing distinctions between guerrillas and mafiosos, and by the humanitarian tugs generated by pictures from places we seldom hear of and people who do not fit our vision of "vital national interests." Still though, as much as Americans might prefer to ignore these tugs, our humanitarian impulses seldom let us. Consequently, these developments, coupled with traditional security concerns, have led to U.S. military forces deploying to assist in security or humanitarian crises scores of times during this decade.

A strategy to deal with dangers such as these that are unprecedented in their complexity requires not a "threat-based" strategy as I spoke to a few minutes ago, but an "interests-based" strategy. The Clinton Administration's *National Security Strategy for A New Century* is an "interests-based" strategy for this unsettled time of transition and changing security

imperatives. Captured within this strategy is both our need to prepare for fighting different types of war (as during the Cold War), and to confront diverse non-traditional security challenges.

The core imperative of this national security strategy is the need for overseas engagement. Thus, ours is a strategy of engagement that seeks to enlarge the community of democratic and free market nations in order to promote our own domestic prosperity, and to check global threats abroad before they threaten our territory and people. Central to this strategy is having the capability to both "shape" the international environment in ways favorable to U.S. interests and global security, and "respond" to the full spectrum of crises that may arise.

The unsettled, ambiguous nature of the international security environment dictates that our strategy address a diverse range of issues affecting national security. It refers to the blurring of domestic and foreign policies; to spreading democracy and human rights; to supporting peace and opening markets; to enlarging and defending the community of nations; to sharing our aspirations and our values; to keeping America militarily, diplomatically and economically strong; to combating the spread and use of weapons of mass destruction; to countering terrorism and fighting drug trafficking. How then does such a broad, flexible strategy relate to non-lethal weapons and technologies?

Well, as written, our *National Security Strategy For a New Century* is a requirements document. No other single document better captures the clear, undeniable <u>need</u> to provide civilian policymakers and military commanders with greater decision and employment options. And there is a direct and growing relationship here between the civilian decisionmaker and the military commander, for with growing frequency, fallout from what the military commander does or does not do ends up back in the policymaker's lap.

Often our instruments of national power are seen as either too weak, or paradoxically, too strong to achieve a desired political outcome. These ideas of "too weak" and "too strong" are related and in some cases virtually inseparable. Many conventional weapons, for example, are ill-suited for urban environments where civilians and military targets exist in close proximity. This situation will become even more grave in the coming years with growing urbanization as the world population increases by more than 86 million people annually. The World Resource Institute, for example, projects that the world population will grow by 45 percent to about 8.3 billion people in 2025 - in just 27 years.

Faced with this situation the United States will require more precise targeting capabilities (both lethal and nonlethal) than that provided by economic sanctions or traditional military methods. Policymakers and military commanders will require greater flexibility.

Nonlethals may expand policy choices by providing a credible capability to use discriminate, measured force to influence conflict or even pre-conflict situations. Depending on the circumstances, nonlethals can supplement or supplant lethal weaponry. Because nonlethal weapons and technologies (both conceptually and in reality) are suited to many situations where human deaths and infrastructure or environmental damage is contrary to our political purposes, they provide decisionmakers increased capabilities and options for resolving vexing political dilemmas. They can potentially:

- lower the threshold at which certain decisions are made;
- minimize self-deterrence or the choice between benign acceptance of a crisis situation and the use of lethal force;
- limit conflict;
- strengthen deterrence by reinforcing flexible response capabilities;
- "buy time" in crises while other instruments such as diplomatic, military, economic or law enforcement are engaged;
- complement and expand the utility of conventional military weaponry.

Some of these points are potentially problematic and vulnerable to critics who would argue that with nonlethals war is more likely because its destructive consequences are reduced. Or that nonlethals demonstrate a clear lack of resolve and could lead to incremental approaches to situations or issues that might not have been adequately thought through. These are not groundless criticisms. But, it is incumbent on policymakers to work through the hard issues surrounding our engagement abroad. Nonlethals do not, as some might suggest, permit policymakers to avoid difficult decisions when contemplating intervention. And nonlethals are not merely the low end of escalatory options. Objectives and desired end states must still be identified beforehand. Further, nonlethals do not mean that war can be fought without the risks of bloodshed and loss of lives.

Policymakers don't normally speak in the hypothetical, but hypothetical examples can illustrate genuine needs. I recall hearing a retired Service Chief note a few years ago that Desert Storm may never have occurred if we possessed the capability to disable Iraqi tank engines prior to their entry into Kuwait - and they knew we had the capability. Extending this example a bit

further: possession of this kind of technology might also have permitted the U.S. to stop all movement along the "highway of death" leading from Kuwait City to Iraq without the intense bombing that occurred, perhaps permitting the Gulf War's termination on different terms.

Similarly, some surmise that certain nonlethal technologies may have given the U.S. Government the flexibility and credible capability to intervene in Bosnia sooner in a limited, yet effective fashion. Or, the absense of nonlethal options could have limited our ability to react when UN peacekeepers were taken hostage by the Serbs, to stop the assault on UN safehavens in Bosnia, or could have forced the resort to lethal options if desperate Muslims had attempted to block UNPROFOR's withdrawal by positioning themselves in front of UN vehicles and tanks in 1995. And, a 1995 Council on Foreign Relations report also mentions that the use of flight-inducing smells and sounds in Somalia "could have offered significant advantages over deadly fire from helicopter gunships...."

More recently, the absence of significant nonlethals in Bosnia could have endangered U.S. troops or undermined the credibility of U.S. forces who could have been forced to retreat in the face of a civilian mob. (Given the choice between "passively holding their ground" or "firing into a threatening crowd of civilians and causing an international incident," soldiers might err on the side of restraint, thereby exposing themselves to greater danger than if they had acted.) And on yet another note, recent events again suggest there is likely a need to develop nonlethal technologies to separate civilians being used as human shields from the military target they are shielding. These types of situations are bound to grow in number. In this instance, nonlethals would serve as the enabler for precise use of conventional weapons.

In these unsettled times with a less certain international landscape -- one marked by increasing ambiguity and complexity -- nonlethals provide great potential. But discussions must move beyond the conceptual. And they must move beyond the narrow vision of nonlethals weapons and systems primarily employed at the tactical level against people (to the exclusion of anti-material).

Nonlethals can expand higher order policy choices too. But what is required is more serious thinking on the subject as well as serious research efforts to find alternatives, and additions, to our current tools. There needs to be broader educational effort aimed at senior policymakers to inform them of the potential of nonlethals - which can then turnaround and feed into the current

requirements process that drives R&D efforts as well as funding priorities. Furthermore, it should not surprise anyone if the identification of a need for greater nonlethal options to deal with the complexities of the contemporary national security environment originate from outside DoD as policymakers acquire a greater understanding of the potential of nonlethals.

Warfare will never be bloodless and military might can never exist merely on the threat, or promise, of nonlethality. But the ability to target an opponent's key vulnerabilities without excessive death and destruction is an appropriate military requirement. It certainly is a political and even a moral requirement. In *Winning the Next War*, political scientist Stephen Rosen argues that as militaries innovate for the future, they should focus on managing uncertainty, rather than on constructing new capabilities tailored to what future wars might look like. We can think of nonlethals as one way to manage uncertainty.

Within the military it is common to say that nonlethals should not tie the hands of the military commander. This is unassailable. But I would submit an addendum: the absence of nonlethality should not tie the hands of policymakers.

In our *National Security Strategy For A New Century*, we have an interests-based strategy. To support this strategy we need "capabilities-based" approaches. Nonlethals provide vast untapped potential capabilities. Earlier I mentioned that policymaking requires options, for options provide flexibility to respond to challenges and to influence actions. The blurring of domestic and foreign policy concerns, the proliferation of security threats and societally-oriented conflict -- in sum, the current international security environment -- require flexible options. Military commanders are prone to say that nonlethal weapons are yet another tool in the commander's kitbag. Well, viable, mature nonlethal technologies also put tools into the policymakers kitbags.

I come back to Sun Tzu:

For to win one hundred victories in one hundred battles is not the acme of skill. To subdue the enemy without fighting is the acme of skill.

I sincerely doubt that the insightful Sun Tzu ever thought about non-nuclear electro-magnetic pulse, accoustic technologies, directed energy, anti-traction materials, or high-power microwaves. But had Sun Tzu been born 2,500 year later, he likely would have…

Development of the Liquid Projectile Weapon

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1.0 INTRODUCTION

UTD Incorporated has performed development work on a an innovative concept for a limited effect (LE) weapon. UTD's concept will launch a slug of liquid a fraction of an inch in diameter, several feet long with sufficient momentum and kinetic energy to inflict a sharp pain at ranges of 50 or more feet, but will not penetrate the skin or cause permanent injury. Dyes and/or scents can be incorporated to mark an individual. UTD envisions two versions: a 3 or 4 shot system with integral magazine and a multiple shot system using a backpack. Both will be self cycling. Energy to fire the liquid slug will be from compressed gas.

1.1 Background

The Liquid Projectile Weapon was originally conceived by UTD in 1995 in response to a percieved need for new limited effect anti personnel weapon technologies. To date, UTD has developed the technology and performed experiments which conclusively prove its feasibility. This work continues to be the subject of an ongoing Internal Research and Development (IR&D) program in which UTD has conducted engineering research, built a Proof of Principle mock up, and performed physical experiments, proving the viability of the concept and demonstrating it to practitioners.

1.2 The Need

A capability gap currently exists in the spectrum of force available to corrections and law enforcement professionals. Table 1 contains a comparison of the capability offered by UTD's Liquid Projectile Weapon concept and other devices presently available. The Liquid Projectile Weapon fills the region bounded by Tasars and pepper (oleoresin capsicum) sprays, effective to only 12 or 15 feet, and the lower limit for ballistic LE devices such as rubber bullets, stingballs, stingbags, and wooden baton skip weapons which become dangerous up close. The Liquid Projectile Weapon will operate in the 0 to 50 or more foot range, filling an existing capability void.

Table 1. Comparison of Options to Capture and Restrain an Individual.

Device/Technique	Range, ft	Physical Effect	Risk*	Remarks
UTD Liquid Projectile Weapon	0-50	Pain, Incapacitation	Low	Can contain marking dyes, irritants, scents, variable power
Voice	0-50	none	Low	Preferred whenever possible
Fists	0-3	Pain, Incapacitation	High	Least preferred, highest probability for injury
Stick/Baton	0-5	Pain, Incapacitation, Injury	High	Most common
Pepper Spray	0-15	Pain, Incapacitation	Med	85% effective, must have face/eye shot
Existing LE Ballistic Devices	60-150	Pain, Incapacitation, Injury	Low	May cause serious injury or death at CLOSE range.
Handgun	2-100	Incapacitation, Serious Injury, Death	Low	With conventional ammunition. High potential to injure innocent bystander
Hand Held Electrical Stun Devices	0-5	Incapacitation	High	Must be in physical contact with suspect
Air Tasar	0-12	Incapacitation	Med	86% effective, only a single shot device

* Physical Risk to Officer using Device or Technique

and understanding of physics and mechanics often leads to a technology breakthrough. The Liquid Projectile Weapon concept is the product of several UTD brainstorm sessions in the LE weapon area. Early studies led to the conclusion that a long, thin liquid slug used as a "bullet" had the following fundamental advantages. Features and benefits of a developed Liquid Projectile Weapon are summarized in Table 2.

- *The degree of lethality should be independent of range provided the slug was launched at a proper velocity and assuming the target was hit on any part of the body except the eye.*

- *The weapon would be simple. Liquid, driven by gas with a piston between the two media, could be ejected through a nozzle, with the use of a simple valving system.*

- *The liquid slug could be used to carry energy to a target, causing a painful diversion of attention. It could be used as well to carry an identifying dye or an irritating agent.*

- *The weapon could be carried as a sidearm, with automatic firing capability. The number of "shots" carried would depend on the mission and could range from a single shot upward, there being about 24 shots available from each gallon of liquid available.*

The Liquid Projectile Weapon will be a simple device. Our Proof of Principle hardware had only two moving parts. This hardware is constructed of stainless steel components and uses conventional buna rubber O ring seals. A production version might be made from aluminum or other material.

A Liquid Projectile Weapon with an integral 3 shot magazine is a natural to physically deter unlawful behavior at ranges from 0-50 or more feet. The ability to engage an assailant beyond the "...critical 7 foot radius" is particularly desired. Unlike other LE ballistic devices, the Liquid Projectile Weapon will be nonlethal at close range. Unlike Tasars or electrical stun devices, the Liquid Projectile Weapon will be effective at ranges over 15 feet. The Liquid Projectile Weapon will be effective both for advancing and retreating targets, unlike pepper sprays which require a clear face shot. Marking and physically stunning individuals without concern as to closeness is the principle benefit during civil disturbances. Unruly individuals at civic demonstrations can be marked, and thus not be able to "melt into the crowd" after throwing bottles or assaulting officers.

The Liquid Projectile Weapon is particularly suited to corrections where arrestees, prisoners, or individuals may become violent or uncooperative. A Liquid Projectile Weapon with an integral 3 shot magazine would be useful to quell small disturbances. A larger capacity backpack version will work well for riots.

Table 2. Features and Benefits of UTD's Liquid Projectile Weapon.

Feature	Benefit	Payoff
Functions as an impact device.	Delivers a strong blow to stun target.	Stun and subdue a person without lethal effects.
Ammunition = pure water.	No clean up: projectile disintegrates on impact.	Projectile can not be used against guards.
Less than Lethal at all ranges.	Better utility in close quarters with minimum liability risk.	Eliminate litigation and settlement costs for prison guards and police officers.
Compressed gas energy source.	Can be stored within prison walls.	Readily available to quickly quell disturbances.

UTD conducted only limited evaluations of the weapons precision or repeatability. We found the it to be adequte, and at one point had 12 consecutive shots at a 33 foot range fall within a 3.5 inch radius which we considered adequate for a close in weapon.

4.0 DEMONSTRATION

The Liquid Projectile Weapon launcher was then mounted on a modified rifle stock. UTD completed detailed impulse-momentum calculations to determine the assembled version's recoil, and found it to compare roughly to a 12 guage shotgun. We conducted over 100 hand held firings including demonstrations around the country for persons in law enforcement, military special forces, corrections, and SWAT.

The response of the user community has been positive. UTD made a short video tape and executive brief which has been distributed nationwide. UTD presented the Liquid Projectile Weapon to attendees of the American Jail Association Conference Session on Less-than-Lethal technology in May of 1997. This gave practitioners the opportunity to see and fire the Liquid Projectile Weapon. It was unusual that every practitioner who has seen the Liquid Projectile Weapon thinks it is a great idea, immediately envisions how it could be used, and understands its benefits. User comments are summarized in Table 3, below.

Table 3. Summary of Practitioner Comments.

User / Scenario	Summary of Practitioner Comments
Prison Extraction Team	Prison guards often encounter inmates who barricade themselves in their cells. Pepper sprays are often ineffective as inmates will cover or turn their faces, leaving guards no option but to enter the cell and physically remove them. This subjects both guards and inmates to injury and liability claims. In contrast to cartridge propelled devices, the Liquid Projectile Weapon can be stored "within the wall," i.e. on prison grounds - since it is powered by compressed gas, instantly available when needed.
Prison Yard & Mess Hall	There is no chance that the Liquid Projectile Weapon's liquid bullet will ricochet and strike an unintended target. There is no clean up when used with water ammunition - just let it evaporate. Adding dye will permit easy identification of instigators who might otherwise escape punishment in the confusion of the moment.
Jails	Sheriff departments are always looking for new options to deal with unruly prisoners, marking and physically stunning unruly inmates at close range within a confined space or cell with no smoke or excessive noise were viewed as advantageous.
SWAT Team	The Liquid Projectile Weapon is LE at all ranges. Current LE ballistic weapon restrictions for minimum range are unrealistic when entering a barricade situation. SWAT Teams simply will not accept a LE weapon with a range restriction: they would rather use conventional weapons. The capability offered by the Liquid Projectile Weapon would reduce the risk to perpetrators and victims during domestic disturbances during which an otherwise law abiding person threatens officers while under the influence of intoxicants.
Civil Unrest	Many LE devices present a risk to users - pepper spray projectiles can be picked up and thrown back at officers or guards. Pepper based products often have restriction based on the space's ventilation. The Liquid Projectile Weapon's liquid slug disintegrates at ranges over 100 feet, and thus poses no threat to innocent bystanders.
Military Peacekeeping	The Liquid Projectile Weapon can be used to control crowds around food, water, dispensing areas where hungry indigents may form an unruly mob. The Liquid Projectile Weapon can be used to keep people at a distance without inflicting serious harm, reducing the "CNN [Cable News Network] factor" or adverse publicity associated with killing or seriously injuring noncombatants.

5.0 SAFETY AND LIABILITY

Current LE ballistic weapons work well at the intended stand-off distance, but at close range they become deadly, and cannot be used without great risk. Existing LE weapons' projectiles strike a target all at once, whereas the liquid slug will interact over a longer period. For example, a 3 foot liquid slug traveling at 300 ft/sec will impact over (3 ft/ 300 ft/sec) = 0.01 second. Compared with a Defense Technology 12 Gauge bean bag, which weighs 1.44 oz and is fired at 280 ft/sec, assuming it penetrates less than 44 mm (the limit of human body penetration for bullet proof vests) with constant deceleration (conservative), the interaction time is ((½) 44 mm/304.8 mm/ft/280 ft/sec) = 0.00103 seconds. Both collisions are fully inelastic, so all kinetic energy goes into deforming the target and/or viscous or visco-elastic deformation of the projectile, but the rate at which a liquid slug's kinetic energy is converted to heat and target deformation is far lower than that of existing LE weapons. The Liquid Projectile Weapon slug weighing 0.3 lb moving at 300 ft/sec will have about 419 lb-ft of kinetic energy, that will dissipate at an average rate of (419 lb-ft/0.01 sec) = 41,925 lb-ft/sec during impact. A 1.44 ounce bean bag LE round will have a kinetic energy of 109 lb-ft at 280 ft/sec, which will be dissipated at an average rate of (109 lb-ft/0.00103 sec) = 105,825 lb-ft/sec - over 2.5 times greater. Liquid Projectile Weapon impact forces are therefore less, as depicted in Figure 3.

The liquid slug loses less speed per distance traveled than a typical LE ballistic projectile. Current LE ballistic projectile velocities drop sharply with range. The projectile's velocity must be high enough at the muzzle to be effective at a distance. The high initial velocity makes these devices lethal at close range, whereas the liquid slug "muzzle velocity" can be engineered for the desired effect at close range, knowing it will be almost the same at a distance. For example, a LE ballistic projectile, shot either from a 37/38 mm gas gun or 12 gauge shot gun, will have an aspect ratio between 1:1 or 1:3. The blunt shape will decelerate quickly from aerodynamic drag. The liquid slug has an aspect ratio of (0.5 in / 36 in) = 1:72. As shown in Figure 5, the liquid slug loses little velocity per distance traveled since the ratio of aerodynamic drag to total kinetic energy is less.

The liquid slug, which is projected at a stagnation pressure of several hundred PSI, will not penetrate the human skin. We surveyed the considerable amount of research done on the dangers of high pressure liquid jets operating at pressures IN THE TENS OF THOUSANDS OF PSI where pressurized liquid sprays are used paint stripping, tank cleaning, and diesel engine fuel injectors. High pressure liquids with abrasives are used to cut materials such as composites, metals, wood, and rock. Two journal articles in particular were of interest: one a Japanese researcher (Katakura, et al) who has conducted experiments of

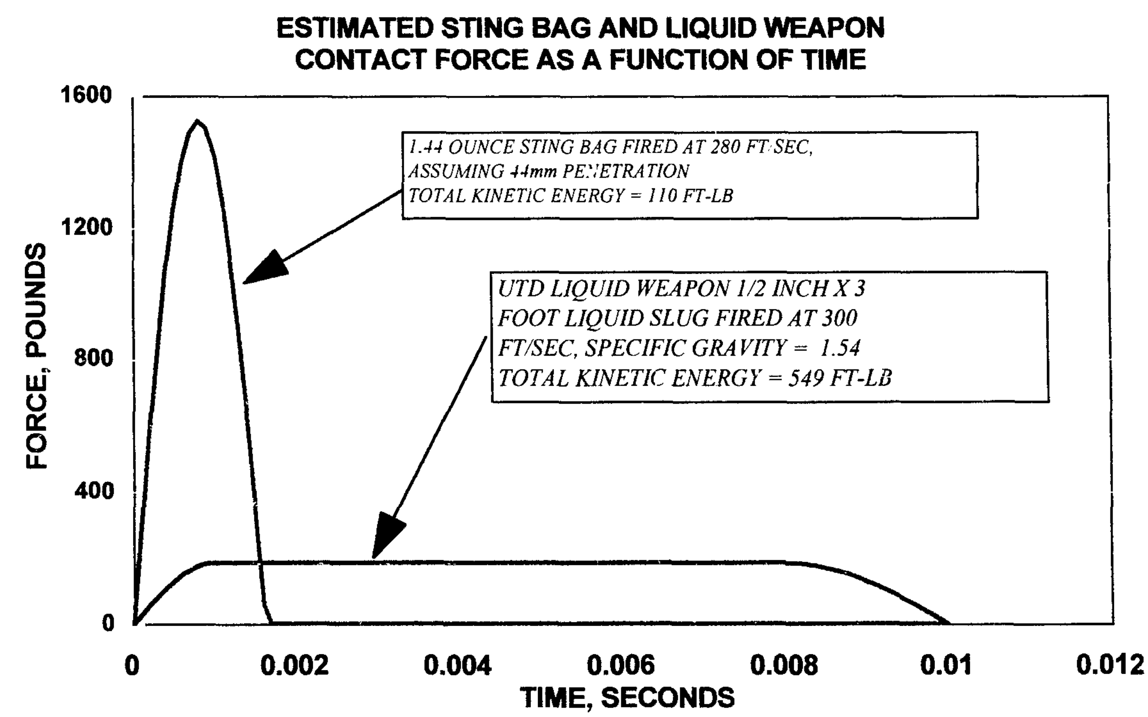


Figure 3. The Liquid Projectile Weapon is Fundamentally Safer Since the Impact Duration is Longer, Resulting in Lower Contact Force.

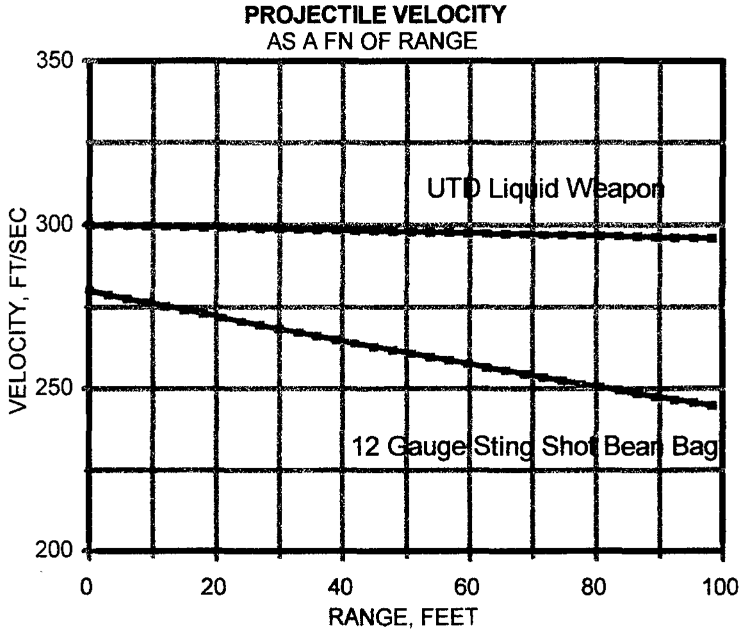


Figure 4. The Liquid Slug
Loses Less Velocity than a Typical LE Round.

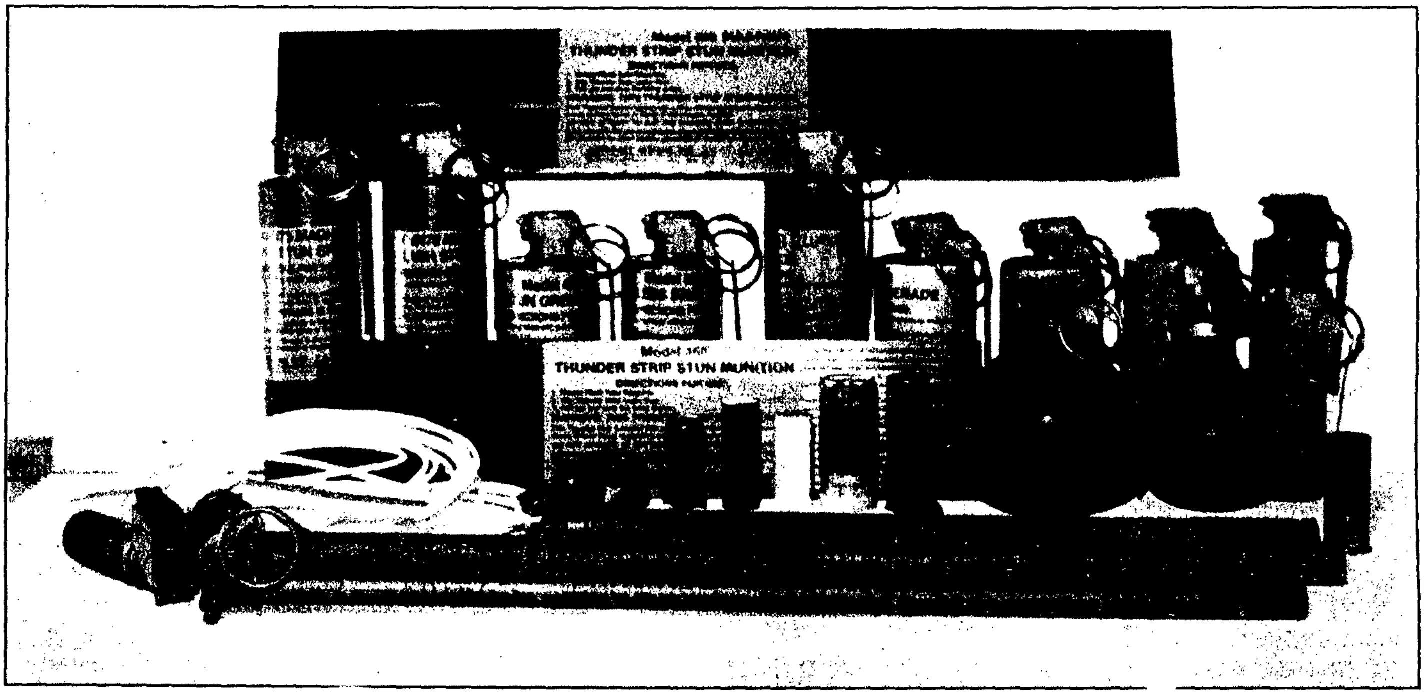
high pressure liquid streams with ox skin, which is very close in strength to human skin. Dr. Katakura proved that a liquid stream pressurized to the same value as the Liquid Projectile Weapon requires a concentrated stream for 10 to 25 seconds to pierce skin. The Liquid Projectile Weapon slug will interact with a target for about 1/100th of one second, clearly indicating its inability to penetrate skin. The foregoing information strongly suggests that the Liquid Projectile Weapon will be intrinsically safe for use on human subjects in both an absolute sense and relative to other LE ballistic devices.

6.0 CONCLUSIONS

UTD has proven the feasibility of the Liquid Projectile Weapon concept. We believe its development and distribution will provide a needed option for the law enforcement and corrections professional.

THE DEVELOPMENT OF BLAST-ACTUATED IMPACT MUNITIONS

SPECIAL PURPOSE LOW LETHALITY ANTI—TERRORIST MUNITIONS



SPLLAT MUNITIONS

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STUN GRENADES AND DIVERSIONARY DEVICES

There is little doubt that the single most important life saving development for law enforcement tactical officers since Richard Davis invented his Second Chance soft body armor in 1972 has been the introduction of Special Purpose Low Lethality Anti Terrorist (SPLLAT) Munitions.

Commonly (and sometimes incorrectly) called "Stun Grenades", "Flash-Bangs" or "Flash-Crashes", these unique life-saving munitions not only provide a decisive tactical advantage to the arresting officers, but have often saved the criminal's lives as well as any hostages and/or innocent bystanders, including the police themselves.

When a properly selected SPLLAT Munition is utilized correctly, even the most violent and dangerous armed felon can be instantly rendered incapable of effectively resisting capture. Since the perpetrator is instantly, but only temporarily, incapacitated he cannot shoot at the police, so, in turn, they do not have to use deadly force to effect his capture. Also, due to the instant incapacitation effect, the criminal will be unable to shoot any hostages present. An added benefit to all concerned will be the dangers caused to innocent bystanders by stray bullets whizzing through walls, down alleys and across streets.

While there a wide variety of SPLLAT Munitions available today for both military and civilian Counter Terrorist, Hostage Rescue, Mob and Riot Control SWAT Teams, they all function in basically the same manner. These devices, normally designed with a short (nominally one second) delay fuze, produce a stunning, disorienting blast and a brilliant, dazzling flash. This "double barrel" effect has proven quite effective in instantly stunning and effectively incapacitating even the most violent felon, permitting his subsequent apprehension with a minimum of risk to the arresting personnel.

Most importantly, due to the unique design of these SPLLAT Munitions, they perform this life saving mission with much less chance of serious injury or death that capture/rescue attempts that utilize only the old fashioned "Thompson Technology": (Shoot 'em all & let God sort 'em out!)

Since these unique, life saving munitions have been available for almost a decade, it is surprising to learn that quite a few agencies are either not aware of their capabilities or, for some reason, do not effectively utilize them in their tactical operations. At least not with the proper procedures necessary to assure their maximum effectiveness.

One of the least understood aspects of SPLLAT Munitions concerns the relative effects of their explosion. Basically, the explosion of either Stun or Distraction/Diversion (yes, there is a very significant difference and it will be covered shortly) consists of both Blast and Flash. Depending on the design of the particular munition, it will produce more or less smoke in conjunction with the explosion. In no case, however, should a properly designed SPLLAT Munition produce any

significant fragmentation, including the violent projection of either the heavy metal fuze body or parts of the grenade body itself.

Of the two basic grenade effects, blast and flash, it is the blast that is by far the most effective of the two. As a result of the feedback from literally hundreds of test firings and dozens of actual "field reports" it has become quite apparent that it is the blast that provides the majority of the effectiveness of the SPLLAT Munitions. While the flash can be very bright and can be expected to "dazzle" a suspect, it will only do so under the proper conditions. If a suspect is in a darkened room, his pupils are dilated, and he is looking directly at the munition when it explodes, it is reasonable to expect that the suspect will be temporarily dazzled and effectively blinded by the bright flash. If, however, the suspect is outdoors in the bright sunlight, or is in a well lighted room, either condition of which will cause his pupils to be contracted, the flash may well prove to be ineffective. Similar non-results can be expected if the suspect happens to shut his eyes (or even blink) just as the munition goes off, or if he has his back turned to the explosion or the explosion is otherwise shielded by furniture or other objects.

The blast, however, has been repeatedly proven to be the most effective portion of the explosion. It has proven to be a truly omnidirectional effect, with only minor shielding being caused by most common objects in a typical room.

The flash may or may not be effective, (because even a dazzled criminal can still fire a weapon), but the blast can be counted on to effectively, and instantly, incapacitate even the most dangerous armed assailant.

It is also important for a tactical officer to understand the terms "Blast" and "Explosion" and to have a feeling for what really occurs when a SPLLAT Munition goes off in the near vicinity of someone.

Basically, the explosion of almost all types of Stun and Diversion / Distraction Grenades/Devices consists of the extremely rapid burning of a mixture of very finely powdered metal "fuel" and a potent oxidizer (which furnishes the necessary oxygen for the rapid combustion). For the technically inclined, the metal fuels are usually magnesium or aluminum and the oxidizers are either potassium perchlorate or a similar chemical with a high oxygen content.

Since both of these chemicals are in the form of fine powders, they have a very large surface area, and thus, upon ignition, will burn extremely rapidly. In the normal sub-ounce size quantities found in most SPLLAT Munitions, this combustion is normally completed in a few thousandths of a second. Due to the heat of the burning, the resulting combustion gases are heated to a high temperature and expand very rapidly, quickly rupturing their container and releasing the compressed gases into the atmosphere. This produces the overpressure we hear (and feel) as the "BANG".

Burning is a surface phenomena and it's speed is directly dependent on several variables. Notably important are the

Multiflash (whose seven submunitions each produce 175 db at THREE Feet, and their M400 Safety Training Grenade are two good examples of the lower powered explosive devices that should never be relied upon to effectively incapacitate an armed felon. These lower powered devices will only distract him and divert his attention for a few seconds. Another important point to remember when utilizing the reusable, solid metal body grenades which have blast vent holes in their ends, is that the holes make the blast from the grenades extremely directional. The full power of such grenades will be experienced only when they are oriented end-on towards the suspect. If the grenade body is lengthwise to the target when the internal submunition explodes, a significant reduction in blast effect can be expected. In other words, the solid metal body grenades which are vented only on their ends can produce wide variations in their effectiveness. For maximum Tactical Reliability, non-fragmenting metal body grenades with side vents along the body are the better choice.

To repeat, anytime decibels are discussed in relation to the effectiveness of SPLLAT Munitions, the actual distance from the blast to the subject must also be included in order to make the information at all meaningful. Even though Precision Ordnance Products' M450 Multiflash Submunitions produce 175 db, they do so only at a maximum distance of three feet, whereas the M429 Thunderflash (a true STUN Grenade) produces the same blast level at a full seven feet.

Also, since the M429's Submunition produces a significantly greater amount of gas upon explosion than the M450's much smaller Submunition, even though both Submunitions happen to explode at their respective 175 db distances from the target, the larger M429's Submunition would be expected to be significantly more effective in incapacitating the suspect.

After determining the power level of the Grenade to be used for the specific task at hand, it is also important to consider the safety features inherent in the design of the Grenade itself. Extensive experience has shown that the safest design of Grenades are those that utilize an ejecting Submunition. Less desirable are those designs that either eject the fuze mechanism, or, even more dangerous, grenades that have the heavy, cast metal fuze screwed directly into the grenade's body where it becomes a potentially lethal projectile when the grenade explodes. Examples of the former design are the U.S.Government's Mark 141 Mod 0, which uses a plastic foam body as the explosive container. It's predecessor, the original FBI-designed M116 A-1 Hand Grenade Simulator, Modified, represents an example of the more dangerous design that throws the fuze. With such velocity that it can penetrate a sheet of 1/2" thick plywood! Such excessive penetration is certainly capable of causing serious injury or even death!.

An additional danger from the fuze-ejecting designs may occur in the event that careless handling of an armed or "live" grenade (pin removed and the safety lever being held down in order to permit rapid employment of the grenade) allows the safety lever to rise enough to permit the striker to slip under

chemical composition of the explosive mixture, the size of the chemical particles, and, to a lesser extent, the type and degree of confinement of the explosive mixture.

In contrast to the burning (or deflagrating) explosive mixtures, true High Explosives normally function by detonating. In a detonation, a shock wave (initially caused by a detonator) actually flashes through the explosive at velocities sometimes exceeding twenty five thousand feet per second. This is several orders of magnitude faster than any burning explosives, and, accordingly, High Explosives are normally many times more powerful than burning explosives. It should be noted that High Explosives can also be burned. When ignited in small quantities out in the open, they generally burn enthusiastically but with nowhere near the speed of flash powder. It is when detonated that High Explosives really demonstrate their true power.

For illustrative purposes, a golf-ball size lump of C-4 plastic explosive, when ignited with a match, will burn for a minute or so. However, that same explosive, if rolled into a one inch diameter "rope" four miles long, and detonated with a blasting cap, would be entirely consumed in about a second.

After bursting the wall of the SPLLAT Munition, the hot, rapidly expanding gases from the burning of the flash powder provide the blast or "over-pressure" shock wave that provides the major effectiveness of the SPLLAT Munition.

This pressure wave is measured in pounds per square inch of over-pressure. The over-pressure being the additional blast pressure in excess of the normal air pressure of approximately 14 pounds per square inch (psi) at sea level. In the normal functional range of true Stun Grenades, this over-pressure is relatively small, being on the order of ten psi or less. In fact, the most effective pressure operating range of a stun grenade is from five to ten psi. At over-pressures much in excess of ten psi, physical injury is likely to occur, while at levels under five psi, only a Distraction/Diversion effect may be encountered.

The most common method of expressing the power level of a blast is in decibels (db). The quantity of a decibel is somewhat tricky to understand, but fortunately, it can be related to psi, which everyone is now aware of - at least somewhat.

Fortunately for modern SWAT Teams, there is a readily available and inexpensive gauging system with which to measure the blast level of the small explosive charges found in SPLLAT Munitions. This is the Anderson Blasgage, available from Accuracy Systems, PO Box 41454 Phoenix, AZ 85080, price $100 per set. This set includes both the Blasgage itself (two 8 1/2" by 11" sheets of 1/8" thick aluminum plate, with ten matching sets of holes which provide the actual "Blasgages"), and 500 sheets of Blast Test Paper. A Special Mounting Bracket w/ Stand is priced at $375 each. (Blasgage extra).

The Blasgage set includes a Conversion Chart which provides a comparison of the relationship between Decibels (db) and Blast Over-Pressure (psi). As a quick inspection of the comparison table will show, there is somewhat of an overlap in the listed ranges of the psi and db. For instance, 175 db can be found

to occur anywhere between .9 psi and 3.0 psi. There are some scientific explanations for this relatively wide variance, but a good, basic explanation is that the relative effectiveness of the blast of a SPLLAT Munition is not an exact science. Anymore than are the terminal ballistic effects of handgun bullets. Anyone long in the field of tactical law enforcement will have heard stories of suspects collapsing from a single hit with a .22 rimfire as well as those who received multiple hits from shotguns or rifles and still went on to kill the arresting officer.

To add some practical meaning to the effectiveness of SPLLAT Munitions, it can be stated that based on the reports of dozens of actual uses in the field, under actual tactical conditions, that a properly selected STUN Grenade when used correctly, will result in an essentially instant incapacitation of even the most determined criminal with something approaching a 90+% reliability. And with a corresponding potential of assuring this instant incapacitation without serious injury.

It is extremely important, however, to correctly define the exact definition of a true STUN GRENADE.

Of additional interest is the fact that decibels are measured by what is scientifically known as a "Logarithmic Function". What this means is that for every ten decibel increase in blast level, you actually double the blast pressure. For instance, in going from 175 db to 185 db, the blast pressure increases from an average of 2.5 psi to about 5.5 psi. Note that the term BLAST LEVEL was used and not BLAST EFFECT. The actual physiological effects on the suspect will be increased in going from 175 to 185 db, but they do not necessarily double.

Years of practical experience and numerous field reports have established the fact that to be considered an effective STUN Grenade, the munition in question must produce a blast level of at least 175 db at a distance of seven (7) feet from the point of explosion. The inclusion of the distance factor is extremely critical in describing the blast (decibel) level of any explosive device, Stun Grenades included.

For instance, a 20 KT Nuclear Bomb will product a blast level of 175 db at a distance of several kilometers. As will an empty, primed .38 Special cartridge case in a 2" Chief's Special if the muzzle is inserted directly into your ear.

Another interesting comparison of pressure levels is that the RATE of pressure application is very important. For instance, if you dive down to the bottom of an ordinary swimming pool, your body will be subject to overpressures on the order of a Stun Grenade. However, due to the relatively slow rate of application, no apparent damage will result. A similar demonstration can be made by slowly pressing the palms of the hands over the ears. Press slowly and only minor discomfort is felt. However, a good sharp slap will create extreme pain, even possible rupturing the ear drum.

Any Grenade or other Munition that produces a blast level below 175 db at 7 feet should be more correctly described as a Diversion/Distraction Device than a true "Stun" Grenade.

Grenades such as Precision Ordnance Products' M450

it and strike the primer in the fuze. One second later the Grenade will function. If it is the Submunition-ejecting design (similar to Precision Ordnance Products' M429, M459, M416 , etc.), the explosive-filled Submunition will be ejected out the bottom of the Grenade's main body prior to it's explosion. If, however, the grenade is of the MK 141, fuze-ejecting design, only the fuze will be ejected and the grenadier will be left holding the explosive charge. At least for a fraction of a second before it explodes! Right in his hand! Obviously the M116 A1 fixed-fuze design will not even give that fraction of a second of a warning. It will just instantly blow the grenadier's hand off!

In addition to evaluating both the basic safety of the design (submunition ejecting or non-submunition ejecting) and the power level (STUN or DIVERSION/DISTRACTION) of the SPLLAT Munition to be selected, the user should also be aware that there are several other very interesting and tactically useful designs of SPLLAT Munitions available on today's market. These include Thunder Rods, which are, as the name implies, long,rod-like Munitions that are designed to be inserted through a small hole through a door or wall. These holes are usually made by using a 12 gauge shotgun with a frangible slug, such as the SHOK LOCK made by Precision Ordnance Products. Thunder Strips (these are nominally foot-long strips of thin, corrugated plastic which are filled with explosive and fired by means of a remote fuze assembly attached to a short length of flexable, hollow plastic Flashtube), which are designed to be inserted under a closed and locked door in order to produce an incapacitating, stunning blast inside the otherwise secure room. There are also Launchable Stun Grenades, which, while physically similar to Thunder Rods, are made with a special Plastic Obturating Cup on one end. In practice, the obturating cup end is inserted into a 12 gauge riot shotgun's muzzle, the safety lever secured by means of either a Shok Lock Adapter or a rubber safety-lever retainin device, the Safety Pin removed, and the M444 is then fired by means of a special M444 Launching Blank. The range of these launchable grenades is approximately 75 meters, and they are a lot more accurate than regular hand thrown grenades. They can even be fired through most standard glass window panes. While not of "Match Grade Accuracy" they are certainly a lot more accurate (as well as longer ranged) than any hand thrown grenade.

For tactical applications requiring the maximum amount of visual acuity, there is even a "Smokless" Stun Grenade available from Precision Ordnance. Their M416 MINI SMOKLESS Stun Grenade represents the current state-of-the-art in SPLLAT Munitions. The M416 is significantly smaller that any similar powered Stun Grenades, and in addition, it's explosion produces less than 10% of the smoke of other types of grenades. Added benefits are that since the M416 is designed with a different type of explosive loading than other grenades, it is also less likely to start fires. Also, it's flash is appreciably less than the other grenades, which can be a benefit when the entry teams are utilizing multiple grenades in darkened rooms. They

will have a much less likelihood of dazzling each other.

While on the subject of "Dazzling" it should be noted that there are also STARFLASH Grenades available from POPI. In addition to the blast and flash of the standard grenades, the Starflash Loading produces a brilliant shower of whitehot, sizzling "Sparklets" that provide a significantly more enhanced Diversion/Distraction Effect. Examples of the Starflash Grenades are the M451 Multi Starflash (similar to the M450, in that it ejects seven individual submunitions) and the M459 Starflash which has a single, large Submunition like the M429 Thunderflash.

The M470 and M471 are Magnum versions of the M429 & M459. These larger grenades contain approximately twice the explosive loading of their smaller contemporaries, and are intended for utilization in outdoor applications, in large buildings such as warehouses and aircraft hangers, and in tactical situations requiring an enhanced degree of effectiveness for the safety of all concerned.

One of the most important safety rules to observe concerning the use of any type of exploding munition is NEVER to expose friendly personnel to the effects of the full power Stun Grenades. No matter how well these grenades are designed and manufactured, there is always the possibility of a malfunction of some type. Or, more likely, the explosion may occur close enough to some other object to propel it with the chance of harmful results. This potentially dangerous situation is known as Secondary Fragmentation. Knowledgeable officers do not test their body armor by wearing it while it is being shot. Neither should they be exposed to potential injury, remote though the chance may be, by needlessly placing themselves in harm's way when training, testing or using the full power stun grenades.

An equally important Safety Rule is to ALWAYS have adequate Medical and Fire Suppression Support immediately available anytime Stun and/or Diversion/Distraction Grenades are used, either in training or in actual tactical operations.

It is also highly recommended that any potential user of these unique, life-saving SPLLAT Munitions make arrangements to attend one of the User Certification Courses that are offered by Accuracy Systems Ordnance Corp. PO Box 41454, Phoenix, AZ 85080. Telephone (602) 433-9375 or FAX (602) 433-9375.

Not only will the student receive a good basic training in the safe and proper techniques to use when employing SPLLAT Munitions, but graduates will also receive a Certificate from the factory stating that the Graduate has been properly trained by the Factory Experts in the Safe and Proper Tactical Utilization of SPLLAT Munitions.

In any event, today's modern tactical officer should always remember it is no longer necessary to shoot and kill a suspect.

In fact, today's Motto should be:

"DON'T SHOOT 'EM - SPLLAT 'EM"!

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ADPA/NSIA Abstract

Company Name: Scientific Applications and Research Associates, Inc.

Point of Contact: Lexi Donne 714-373-5509 x 226 email: adonne@sara.com

Concept: High Energy Toroidal Vortex for Overlapping Civilian Law Enforcement and Military Police Operations. The prototype toroidal vortex launcher was built on a Phase I SBIR sponsored by the USAF Phillips Lab. Dean Lawry is the Technical Monitor. The prototype is shown in Figure 1.

The High Energy Toroidal Vortex (HETV) is a non-lethal device whereby the targeted person is knocked down by an energetic toroid. Figure 2 is a frame of data from an August 1997 test series, showing a HETV in flight. Several missions are envisioned for this device including: hostage/barricade situations arising from terrorist and other criminal activities, rapid response to and resolution of violent outbreaks in jails and prisons, anti-terrorist response capabilities including the protection of critical and sensitive areas and facilities, response capability for riotous mobs and civil unrest as may be experienced at domestic or foreign location military bases and installations, and anti-gang and drug response capability.

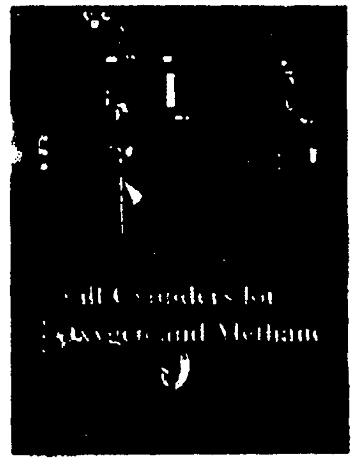

FIGURE 1. Integrated HETV setup for cold flow tests. Unistrut stand simplifies testing.

The HETV is capable of carrying a large amount of energy in the vortex structure. This energy is stored in the HETV by means of the forward kinetic energy, the core rotation kinetic energy and the rarefaction zone in the annular vortex core. Recent tests with the prototype indicate that the vortex is capable of 0.5 to 0.8 times the speed of sound with an energy of 500 joules or more.

The HETV currently operates on methane and oxygen. It is a simple tube with a combustion chamber on the back, two small fill tanks and a donut forming flat plate on the front. CFD analysis is proposed for the Phase II effort, to enhance the energy containment and repeatability of the device.

Conversations with the Los Angeles Sheriff Dept., Los Angeles Police Dept. and the National Law Enforcement Corrections Technology Center indicate a small hand held device would be of use in multiple tactical scenarios and that a mobile unit would be of greatest interest in prisons and jails.

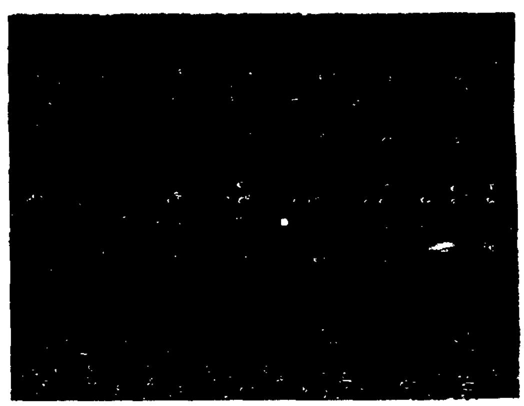

Figure 2. Vortex generated during Camp Pendleton Testing. Blackbody calibrator and pressure transducers visible in the background.

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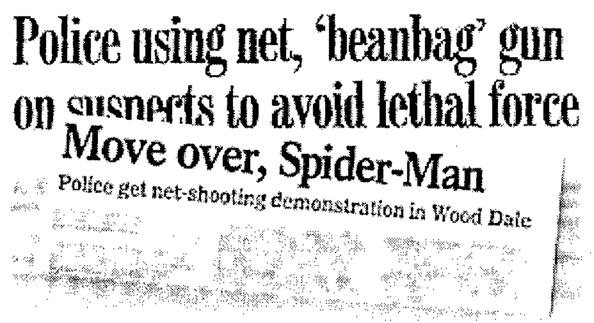
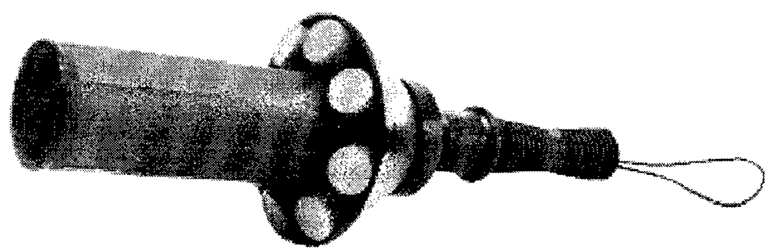
Officer Hand Launcher: OHL5 Overview

- Designed and manufactured in Leipzig, Germany by GETEC GmbH
- Complete range of Net Launchers for every application
- Used against felons, intruders, fugitives, assailants, animals
- In use across the United States by Police Departments and Emergency Response Teams
- Provides a true non lethal response to aggression while severely restricting movement to facilitate arrest


Police using net, 'beanbag' gun on suspects to avoid lethal force

Move over, Spider-Man

Police get net-shooting demonstration in Wood Dale



Law Enforcement Agencies have come under enormous pressure in the past few years to move away from traditional armed response against fugitives and employ a variety of new less than lethal weapons.

Less than lethal includes chemical sprays and electrocution in many imaginative forms. Soft projectiles can incorporate more chemicals to disorient and impair the target, or simply cause tissue damage to subdue aggressive actions. Much has been written about sticky foams and other devices that might be more at home on a movie set, and are yet to find their way into the commercial market.

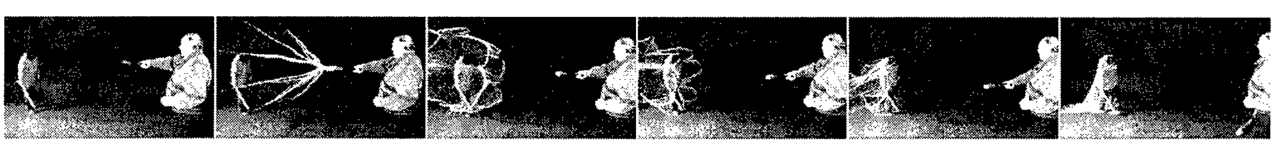
The Officer Hand Launchers by GETEC provide Law Enforcement Personnel with the opportunity to significantly restrict the target's movement and facilitate arrest without relying on unpredictable and dangerous reactions to noxious chemicals, projectiles or electrocution.

Officer Hand Launchers are now in use across North America and around the world. Police Emergency Response Teams have used OHL5s in the field to successfully confront and arrest subjects who did not react to chemical deterrents and other measures. Departments are now moving from an ERT-only application to more general use by Officers.

The OHL5 is just one of a complete family of Hand Launchers designed to meet specific applications. New models are being developed throughout 1998 and will be introduced on our internet web site at www.getec.com as they become available.

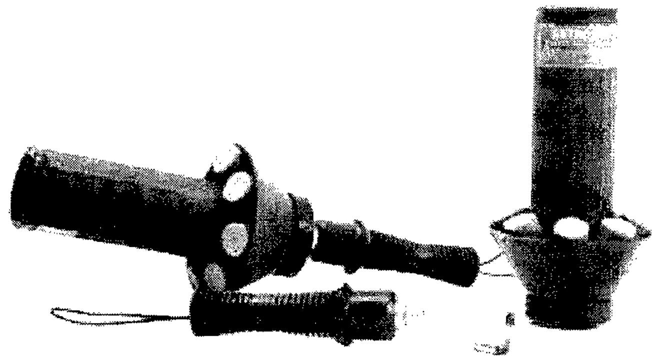
OHL5 SPECIFICATIONS

- **LAUNCH READY**
  870 GRAMS
  395 MM LENGTH
  130 MM MAX WIDTH
- **CAPTURE NET**
  5.0 X 5.0 M
  70 X 70 MM MESH
  140 NEWTON TEAR
- **PROPELLANT**
  9 MM
  CO2 CHARGE
  PLASTIC BLANK
- **PERFORMANCE**
  170 KPH LAUNCH
  2 METERS<7.5 JOULE
  2.0 M MIN RANGE
  5.0 M MAX RANGE
  2.5 M EXPANSION

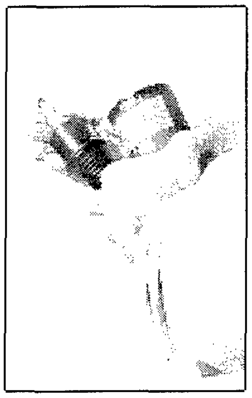


Officer Hand Launcher: OHL5 Operation

- Three components make up a complete OHL5.
- The Hand Launcher is reusable and contains the firing mechanism to launch the Net. It weighs 220 grams and is 170 mm long.



- Gas Cartridges manufactured by Dynamit Nobel provide the propellant and are inserted into the Hand Launcher. They are 9 mm plastic blank cartridges containing carbon dioxide and a propellant powder (single-base with a low portion of nitroglycerin). Consult the Material Data Safety Sheet for additional information.
- The Net Cannon is 130 mm by 225 mm and weighs 650 grams. The Cannon contains the 5 x 5 meter Net which launches at 170 kph. Eight external lead expansion weights covered in protective polystyrene foam open the Net to a 2.5 x 2.5 meter window, enveloping the target in less than one second. The Nets are manufactured from an advanced thread, selected for high tear strength and light weight. A tight mesh of only 70 square mm restricts hand movement through the net, and the captive is easily controlled and handcuffed.



- Operation of the OHL5 is a simple procedure for any professional trained in the use of firearms.
- Insert the Gas Cartridge into the small chamber at the top of the Hand Launcher.

- Align the threads on the Hand Launcher and Net Cannon and twist one against the other approximately 270 degrees or until a snug fit is reached.
- To ready the OHL5 for firing, hold the Hand Launcher in one hand and lightly pull back on the trigger cord. This action engages the firing pin, which is activated by pulling back the trigger ring at the top of the Hand Launcher with the thumb or two fingers.
- Note that a safety position is available on the trigger ring, which is reached by rotating the trigger to the right.
- When aiming and firing the OHL5, a clear window of deployment must be calculated to determine the trajectory of the Net. Obstacles such as tree branches and furniture will upset the path of the Net. Aiming the OHL5 in the manner of a flashlight, target the chest area at no less than 2.0 meters to no more than 4.5 meters for optimum effect.
- The Net and Expansion Weights should not pose a significant impact danger to the target. Note that injury to soft tissue such as the eyes can occur with any projectile including those products made by GETEC.
- Only those professionally trained in the proper use and deployment of firearms and security products should use GETEC products.

GETEC® GmbH Leipzig designs and develops security systems and defense products for a wide range of consumer and government needs. GETEC products have received numerous international patents for their design and unique technology. Access to a worldwide network of distributors and additional information on GETEC is available at www.getec.com.

To find out more about GETEC products, contact **Michael Wolf** at Getec America Corporation in Seattle. Our address is 1420 5th Avenue, Suite 2200, Seattle WA 98101 and the numbers are 206.224.7607 (b) and 206.224.2880 (f).

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GETEC in the media: 10.07.97

Baltimore Sun 9/30/97

Baltimore police have a new weapon to help subdue dangerous people without shooting them.

In addition to a 'beanbag' gun used to disable armed suspects that was used for the first time last month, the Police Department now has a (268 sq ft) net to cast over suspects.

It's not quite Spiderman shooting a web from his wrist, but **officers used the device for the first time last week to capture a distraught woman who was reaching for a butcher's knife.**

"We were happy with the result," said Maj. Bert L. Shirley, commander of the tactical section. "We're still experimenting with it to see what situations it can be used in, but we prefer this to deadly force."

The device is a small cylinder that resembles a wand. An officer aims it and presses a button. The folded net is ejected and spreads over the target. It has a range of 15 to 18 feet.

The issue of less-lethal force was highlighted after a controversial shooting Aug. 9 outside Lexington Market in West Baltimore. As a bystander videotaped the confrontation, Officer Charles M. Smothers II fatally shot James Quarles, 22, after Quarles refused to obey repeated demands to drop a knife. Smothers was cleared of criminal responsibility but faces an internal review.

One of the issues police are studying in the six-minute confrontation in the Quarles case was whether police had time to call tactical officers, who are the only officers who have the 'beanbag' gun – which fires a bag of lead pellets – and the net. Both devices were acquired before the shooting.

In the most recent case, police said they responded Friday to a report of a 60-year-old mentally ill woman who had assaulted her apartment building manager and barricaded herself in a room in the 1400 block of N. Carey St. in West Baltimore.

Tactical officers forced their way into the building and sprayed the woman with tear gas as she went to a kitchen. Police say the chemical spray had no effect.

Police fired the net as the woman ran to a back bedroom with her hands in her purse. Police said that after the woman was subdued, they found a butcher's knife in her purse. The woman was not charged but taken to a hospital for a psychiatric evaluation.

Police using net, 'beanbag' gun on suspects to avoid lethal force

By Peter Hermann
Sun Staff

Baltimore police have a new weapon to help subdue dangerous people without shooting them.

In addition to a "beanbag" gun used to disable armed suspects that was used for the first time last month, the Police Department now has a 12-foot-square net to cast over suspects.

It's not quite Spiderman shooting a web from his wrist, but officers used the device for the first time last week to capture a distraught woman who was reaching for a butcher's knife.

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Baltimore Police Department Incident Sheet

TACTICAL OPERATIONS EMERGENCY TRUCK	INCIDENT SHEET
TYPE OF INCIDENT: VIOLENT MENTAL CASE	DATE/TIME: 26 SEPT 97 1100 HRS
LOCATION: 1431 N. CAREY APT. 306	COMPLAINT: 7118301

NOTIFIED BY KGA TO RESPOND TO 1431 N CAREY FOR A VIOLENT 10-31 MENTAL. UPON ARRIVAL 7811 ADVISED THAT A 60 YR OLD FEMALE, WITH A HISTORY OF MENTAL ILLNESS HAD ASSAULTED THE BUILDING MANAGER, AND THEN BARRICADED THE APARTMENT DOOR. WE USED A HYDRAULIC TOOL TO ENTER, OBSERVED SUBJECT ATTEMPTING TO ENTER KITCHEN, UNABLE TO SEE HANDS OF SUBJECT, I USED FOAM MACE. SUBJECT ATTEMPTED TO RUN INTO REAR BEDROOM, ATTEMPTING TO GET HAND IN PURSE, I THEN ACTIVATED THE HAND HELD NET. **SUBJECT WAS TAKEN DOWN WITH USE OF NET**, AND SUBDUED. INSIDE PURSE WAS A 8" BUTCHER KNIFE. NO INJURIES TO SUBJECT AND POLICE OFFICERS.

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GETEC in the media: 07.24.97

Chicago Daily Herald 7/24/97

The Shocker and his villainous cohort Venom prove no match for Spider-Man's spinning webs.

Although the fictional Peter Parker won't be swinging from Wood Dale buildings anytime soon, residents can sleep well at night knowing their town has the next best thing.

The Wood Dale Police Department is the first cop shop in the area to test a net-shooting device that promises to trap bad guys in a tangled web of confusion.

"Officer Hand Launcher" made its debut Thursday outside the police station as the product's marketers held a demonstration for officials and police from Des Plaines, Elk Grove Village, Elmhurst, Rosemont and Schaumburg.

"We're always looking for different ways to contain a person while using the lowest level of violence possible," Wood Dale Cmdr. Frank Biniewicz said. "It's a very effective and non-combative way of neutralizing a person."

An officer aims a flashlight-looking device that weighs only two pounds at the suspect. He or she triggers a cartridge that launches a 268-square-foot net over the target.

The net travels at about (100 miles per hour), though it only will trap a target up to 15 feet away. The nets are made from an advanced thread and aren't easily torn or sliced and further entangle suspects as they try to break free.

Bensenville-based New Millennium Products plans on marketing the launcher across the state. So far, it's mainly used by federal armed forces and special groups including a Seattle SWAT team.

It gives police another option in detaining fugitives or suspects causing harm to others rather than using force, a nightstick or even a gun.

"If you look at all the publicity in the news these days, there's a lot of police being accused of using too much power or in beatings," said Itasca resident Craig Carone, part-owner of the company (New Millennium Products).

"This not only protects the officer and the suspect, but it protects the department and taxpayers from a lawsuit."

For hosting the demonstration, Wood Dale received a launcher, net cannon and gas cartridge worth almost $300. The launcher is reusable, but each net costs $158. The department plans on training its sergeants and possibly purchasing more equipment if officials find it works.

Move over, Spider-Man

Police get net-shooting demonstration in Wood Dale

LASER DAZZLER

9/30/97

LE Systems has developed a new tool, for today's Law Enforcement, Corrections & Military Communities. Under the sponsorship of DARPA's Joint Program Steering Group, LE Systems has completed and delivered, ten prototype non-lethal laser flashlights. The Laser Dazzler is designed to allow the officer to "reach out" to their suspect.

Working with both Phillips Laboratory, [PL/LIDA], and the National Institutes of Justice, [NIJ], the design incorporates features which allows the officer to disorient, confuse, and distract the suspect, without causing bodily harm.

Eyesafe at the aperture, the Laser Dazzler will have a temporary effect on the officers adversary. It presents to the target, an "optical wall", which will cause most suspects to turn away from the light. Another feature of the flashlight is the "strobe" effect, built into the programmable power supply, which modulates the laser, to add to the distraction.

During the course of the devices development, LE Systems has interacted with numerous potential endusers. Comments have ranged from, "how soon can I have one?", to, "if only we had this yesterday"

Today's Police Officer, Corrections Officer or Soldier in peace-keeping efforts, has many choices when dealing with a potentially violent situation. Unfortunately, with these choices come limitations. Traditional tools such as batons, pepper sprays and defensive tactics require the Officer to place him or herself within close personal distances with their adversary, which greatly increases the chance of injury. Less-Lethal munitions (Bean Bag, Baton, & Net rounds) allow only a slightly greater distance, but can (and have) caused unwarranted lethal injuries. These devices often escalate encounters because of the close proximity the operators must get have with their targets. Firearms bring a tragic end to some situations where no other means are available to safely control an individual from distance.

Distance is the key to controlling potentially violent encounters. Creating a safety zone for the officers involved and a time cushion to allow a variety of decisions on the use of force continuum does this. Having a Laser Dazzler, in the inventory, will give the officer the ability to reach out beyond 25 meters, to ranges up to hundreds of meters. The Laser Dazzler will give the officer or soldier an "optical shield", even in daylight, and will give the officer a choice, an upper hand, and most of all time, before resorting to lethal force.
LE Systems Inc. expects to be able to begin, "limited", deliveries of the Laser Dazzler by the end of 1998, to selected endusers. The initial device incorporates, "off-the-shelf" technology, and the second generation will be "smaller, lighter, and less expensive".

Keywords: Laser, Non-Lethal, Dazzle, 532nm, and Eyesafe

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For further information contact: Richard Nelson, Program Manager - Laser Systems

Laser Dazzler for Non-Lethal Force Applications

LE Systems has developed a new tool, for today's Law Enforcement, Corrections & Military Communities. Under the sponsorship of DARPA's Joint Program Steering Group, LE Systems has completed and delivered ten prototype non-lethal laser flashlights. The Laser Dazzler.is designed to allow the officer to "reach out" to their suspect.

Working with Phillips Laboratory, [PL/LIDAI, and the National Institutes of Justice, NIJ, the design incorporates *features,* which allows *the* officer to disorient, confuse, and distract the suspect, without causing bodily harm.

The Laser Dazzler is essentially a handheld, green, 532mn diode pumped laser. The *532nm* frequency was chosen for it's unique ability to react with the human eye in both daylight and reduced light conditions, causing disorientation and confusion. The second advantage is the range of green light is, "orders of magnitude" greater than white light

Eyesafe at the aperture, the Laser Dazzler will have a temporary effect on the officer' or soldier's 5 adversary. It presents to the target, an "optical wall", which will cause most suspects to turn away from the light. *Although a minimal* use of force, the Laser Dazzler gives the user a "time cushion" that is found in no other device. This "time cushion" allows a safe standoff distance, greater officer safety, surrender, de-escalation, or other force options to be exercised. Another feature of the flashlight is the "strobe" effect, built into the programmable power supply, which modulates the laser, to add to the distraction I disorientation effects.

In encounters between law enforcement personnel and persons demonstrating passive resistance or emotionally disturbed individuals, the distance between the two can be directly related to force needed to control the individual and the potential for violence. With conventional tools currently available to law enforcement, the officer must get within close personal distances to employ any non-lethal measures. Closing this distance increases the risk to the officer and to the escalation of the event. Less-lethal measures can increase the standoff distance to approximately *25* meters, but the potential for injury or even death is real.

Non-Lethal devices, such as the Laser Dazzler, are not meant to replace anything tools currently used in law enforcement. They are to add to the versatility of law enforcement, dealing in today's litigious world. The goal of non-lethal devices is greatly different from less-lethal devices. Non-lethal devices offer temporary control, their effects are uncomfortable, they cause no injury, and there are no lawyers. Less-Lethal devices offer a higher level of control, but the potential for injury or death must be carefully weighed before use.

The Laser Dazzler, in its current configuration, can be effectively used beyond distances of fifty meters. This allows for a large "time cushion", enhanced officer safety, and a tremendous effect referred to as a "Psychological Takedown". This is the ability to effectively interact with a subject, by overwhelming the senses without injuring, and without getting within close personal distances.

The Physical design of the Laser Dazzler is critical. This device is designed to look like and be operated like a typical law enforcement flashlight. This is to maintain a consistency in training with the officer. All of the physical skills needed to utilize the Laser Dazzler, as a stand-alone device or in conjunction with a duty firearm, are the same as those currently used with a flashlight. (Figure 1)

The mechanical design of the Laser Dazzler is very straightforward. The assembly consists of four subassemblies. The "Patent Pending" LE System resonator, a four cell rechargeable battery pack, computer controlled power supply, and the Beam Expander assembly. Each subassembly is modular, allowing for independent assembly, and computerized testing prior to fina! assembly.

LE Systems inc. expects to be able to begin, "limited", deliveries of the Laser Dazzler by the end of 1998, to selected end users. The initial device incorporates, "off-the-shelf technology, and ~e second generation will be "smaller, lighter, and less expensive

Keywords: Laser, Non-Lethal, Dazzle, *532nm*3 and Eyesafe

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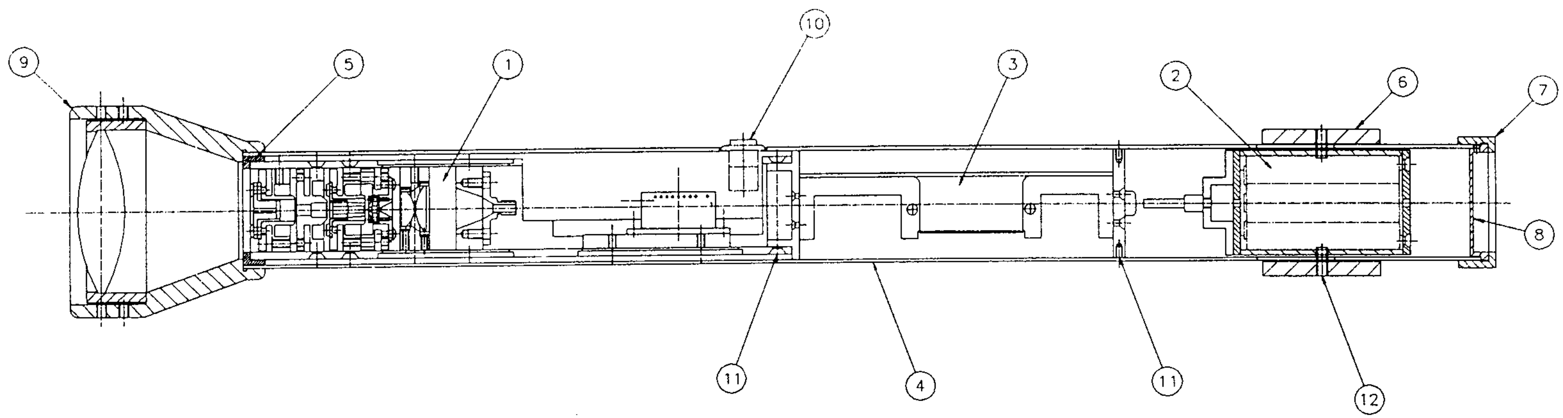
E-Mail: LBSYSTEMS®AGL.COM

REVISIONS					
LTR	DESCRIPTION	ECN	NAME	DATE	CHK



ITEM	QTY.	DESCRIPTION	PART NUMBER
12	2	SHSS, #10-32 X .50 LG	
11	11	FHCS, #6-32 X .25 LG	
10	1	PUSHBUTTON (NEWARK)	
9	1	ASSY, BEAM EXPANDER	33007-78
8	1	INSERT, PANEL, CONTROL	33007-71
7	1	CAP, END	33007-53
6	1	RING, SLIDE	33007-58
5	1	SPACER, RESONATOR	33007-49
4	1	HOUSING, OUTER	33007-48
3	1	ASSY, POWER SUPPLY	33007-03
2	1	ASSY, BATTERY PACK	33007-02
1	1	ASSY, RESONATOR	33007-01

PARTS LIST

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED
TOLERANCES
.XX = ±.010 FRACTIONS = ±1/64
.XXX = ±.005 ANGLES = 0°-30'
BREAK SHARP EDGES .005-.020
FILLET RADII .005-.020
DIMENSIONS ARE IN INCHES

DO NOT SCALE DWG.

MATERIAL XXX

FINISH XXX

	NAME	DATE
DRN		
DESG	L. BILLINGS	5/31/97
CHK		
APPR		

PROJ. NO. DAAE30-98-C-0070

MODEL XXX

L E Systems Inc.
GLASTONBURY, CT 06033

TITLE ASSY, FLASHLIGHT

DWG NO. D-33007-00 REV 4

SCALE FULL

SHEET 1 OF 1

SAND97-2392C
Submitted for presentation at the Non-Lethal Defense III, February 24-26, 1998,
Johns Hopkins Applied Physics Laboratory, Laurel, MD

Next-Generation Diversionary Devices

Mark C. Grubelich, Susan H. Fischer, and Paul W. Cooper
Sandia National Laboratories
PO Box 5800, MS-1453
Albuquerque, NM 87185-1453

ABSTRACT

Diversionary devices are of use in a wide variety of military and law-enforcement operations. They function to distract and/or incapacitate adversaries in scenarios ranging from hostage rescue to covert strategic paralysis operations.

The current Mk141 diversionary device (also known as "flash bang" or "stun grenade") is used in military and law enforcement operations. The desired results of the Mk141 are to produce a disorienting flash of light and a shock wave to temporarily incapacitate or disorient adversaries without inflicting permanent damage.

There are several disadvantages to using the Mk141. The energetic material used in the Mk141 is classed as a 1.1 explosive, making storage, transportation, and manufacture difficult. The energetic material produces a high point-source pressure (on the order of 5 ksi at the surface of the device) in order to produce the desired far-field diversionary effects. Consequently the Mk141 can produce serious injuries and fatalities in the near-field. Furthermore, smoke produced by the device hinders target acquisition.

We have been developing a next generation diversionary device to satisfy the requirements of the less-than-lethal criteria. Less-than-lethal requires the incapacitation of personnel while minimizing fatalities, permanent injury, and unplanned collateral damage. This next-generation device is capable of producing the desired far-field diversionary effects without high near-field pressures. This device also exhibits reduced smoke production which allows for easier target acquisition

We have demonstrated proof-of-concept of the next-generation diversionary device. The next step will be to develop a prototype device.

Designated points of contact for this work are Mark Grubelich, (505) 844-9052, mcgrube@sandia.gov and Susan Fischer, (505) 845-8092, shfisch@sandia.gov.

Next-Generation Diversionary Devices

Mark C. Grubelich, Susan H. Fischer, and Paul W. Cooper
Sandia National Laboratories
PO Box 5800, MS-1453
Albuquerque, NM 87185-1453

INTRODUCTION

Diversionary devices are used in a wide variety of military and law-enforcement operations. They function to distract and/or incapacitate adversaries in scenarios ranging from hostage rescue to covert strategic paralysis operations.

There are a number of disadvantages associated with currently available diversionary devices. Personnel safety is of paramount importance as serious injuries and fatalities have resulted from their use both operationally and in training .

Desired improvements to these devices include protection against inadvertent initiation, lower smoke production, the elimination of the production of high-velocity fragments, and increased light output.

We have been developing a next-generation diversionary flash-bang device that would provide increased safety, lower smoke production, no secondary high-velocity fragments, higher light output, and the potential for user-tailorable output.

BACKGROUND

In the United States, the first diversionary devices used were M116A1 hand-grenade simulators. The M116A1 used a pull-wire fuze lighter and a piece of time-delay blasting fuze that provided a delay of 15 to 30 seconds. This device contained 35 grams of a photoflash mix.

The FBI Hostage Rescue Team modified the M116A1. An M301 fuze assembly, used in smoke grenades, was employed to provide a shorter (two-to-four-second) delay. This was done by removing the pull-wire fuze lighter and delay fuze. The M301 fuze was installed in the cardboard body of the M116A1; a potting compound was used to seal the assembly. Problems associated with these devices included occasional flashthroughs in the fuze assembly (leading to "instantaneous" functioning), fuze function failures, the ejection of the fuze at potentially lethal velocities ranging from 80 fps to 180 fps, fires as a result of smoldering cardboard body fragments, and excessive smoke production.

As a result of the US military's requirement for an next-generation operational device, Sandia National Laboratories was asked to design a device addressing these problems. The new device,

the Mk141 mod 0 device, contained 17.5 grams of flake aluminum and potassium perchlorate flash powder. Less smoke was produced due to the decrease in the amount of material in the charge as well as better combustion efficiency. The design had a molded plastic fuze assembly which eliminated flash-through problems. It was ejected at a low velocity (~20 fps) prior to the ignition of the flash powder. This was accomplished by igniting a small pyrotechnic charge which separated the fuze assembly from the Mk141's main body. A short delay column, integral to the main body, subsequently ignited the flash-powder charge which functioned within approximately a foot of where it was thrown. The body was made of fire-retardant urethane foam to eliminate any high-velocity high-density fragments and to reduce the probability of secondary fires. The body was colored black for covert operations.

The original M116A1, the modified M116A1, and the Mk141 are pictured in Figure 1. Figure 2 shows a disassembled Mk141.

Figure 1. M116A1 mod 0, M116A1 mod 1, and Mk141.

Figure 2. Disassembled Mk141.

PERFORMANCE OF THE Mk141

The Mk141 produces an internal pressure of about 27 ksi with a rapid rise to the peak pressure, as is shown in Figure 3. This peak side-on pressure decays with distance as is shown in Figure 4. This overpressure, combined with intense light output (which has never been characterized), temporarily distracts and/or incapacitates adversaries.

Unfortunately, the contact and very near-field effects of the Mk141 are of sufficient magnitude to cause permanent injuries and/or fatalities due to the overpressure as well as high-velocity secondary fragments. The degree of injury depends on peak pressure and the duration of the overpressure wave.

Survival curves have been compiled for a number of conditions. Figures 5, 6, and 7 show these curves for several orientations of the subject with respect to the shock wave. The damage thresholds also depend on the presence or absence of a reflecting surface close to the subject. This effect is illustrated by comparing Figures 6 and 7. Similar curves are available for ear damage. The threshold for eardrum rupture is about 4 psi.

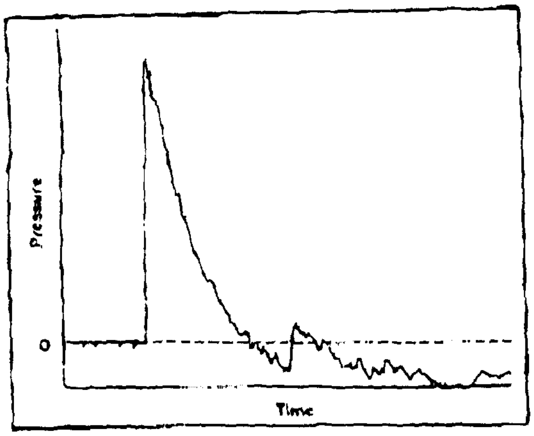


Figure 3. Typical pressure trace for the Mk141.

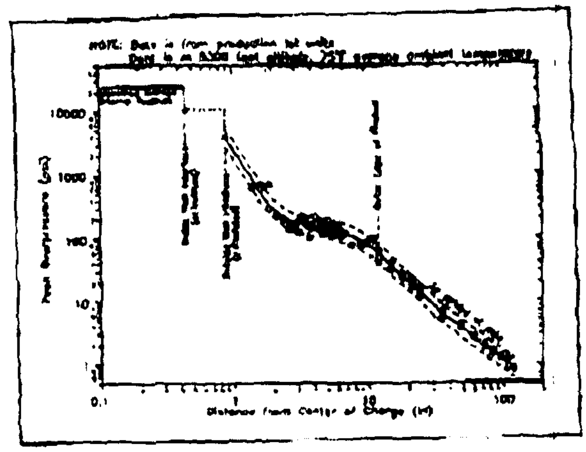


Figure 4. Pressure vs distance data for the Mk141.

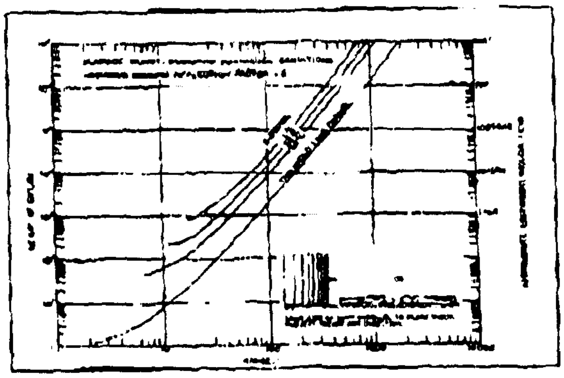


Figure 5. Predicted survival curves for man exposed in the free stream to surface burst of TNT where the long axis of the body is parallel to the blast winds.

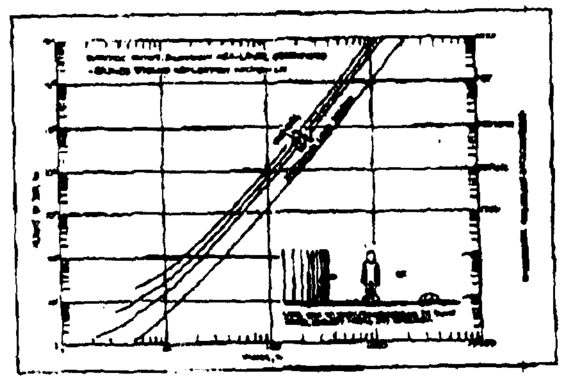


Figure 6. Predicted survival curves for man exposed in the free stream to surface bursts of TNT where the long axis of the body is perpendicular to the blast winds.

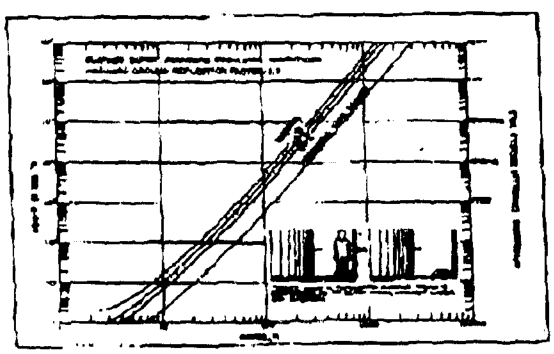


Figure 7. Predicted survival curve for man exposed to surface bursts of TNT where the thorax is near a flat rigid surface reflecting the blast wave at normal incidence.

Other safety concerns also exist. The Mk141 utilizes a "flash powder" mix of potassium perchlorate and aluminum which is a class 1.1 explosive. This material is sensitive to shock, thermal, electrostatic, and mechanical ignition stimuli. These devices are also susceptible to sympathetic detonation and initiation by bullet impact. Additionally, the Mk141 device must be handled as a destructive device during storage and shipping as it is, effectively, a small bomb.

NEXT-GENERATION FLASH-BANG DIVERSIONARY DEVICE

General Description

Based on recent research, coupled with the desire for an improvement in safety, a safer and more versatile diversionary device can be developed using the combustion of a fuel delivered by the

device and the oxygen present in the ambient air. This next-generation device ejects a powdered fuel that mixes with ambient air and then auto-ignites. (This process is similar to the ignition of propellant gases in guns resulting in a "muzzle flash" event or the ignition of dust in a grain-elevator explosion). The operation of this device produces a fuel-air combustion reaction. Since a combustion process is more spatially and temporally diffuse than the detonation of an explosive, a longer pressure pulse with a slower rise to the peak pressure results. This produces a near-field peak overpressure that is several orders of magnitude lower than that of the Mk141. The desired far-field effects of acoustic and visual alarm are preserved.

Advantages

There are many advantages of this next-generation flash-bang device.

- Due to the reduced near-field peak overpressure, the possibility of permanent damage to subjects exposed to the near-field pressure wave would be greatly reduced.
- The acceleration of any near-field objects produced by the overpressure would be less, making serious injury due to secondary high-velocity fragments much less likely.
- The nonexplosive nature of the powdered-metal fill would allow the devices to be stored and shipped with fewer (if any) restrictions.
- The fuel-air reaction will produce less smoke since the products of combustion would not contain potassium chloride. Thus, target acquisition upon entry would be enhanced.
- The next-generation diversionary device's "yield" could be customized in the field. The acoustic and light output could be adjustable by increase or decrease of the fuel charge during each particular operational scenario.

Metal Powder Fuels

For the next-generation diversionary flash-bang device discussed here, aluminum was selected for the fuel. Fine aluminum particles have high reactivity in air and good combustion efficiency without being pyrophoric. This is accomplished commercially by passivating even submicron aluminum particles to produce a thin inert aluminum-oxide layer while still allowing the underlying aluminum to remain active.

EXPERIMENTAL CHARACTERIZATION

In preliminary tests, we have demonstrated proof-of-concept of the next-generation diversionary device. This was accomplished by expelling twenty-five grams of 3μ aluminum powder (Valimet H3) from a one-inch inside-diameter by six-inch-long tube with 2.5 grams of 4Fg black powder (used as a gas generator and igniter charge). The residual hot gases and particles from the black powder ignite the aluminum powder as it mixes with air.

The experimental setup is illustrated in Figure 8. The test configuration allows the aluminum powder to be launched vertically resulting in a very directional output. This potentially allows for next-generation coupling to the target.

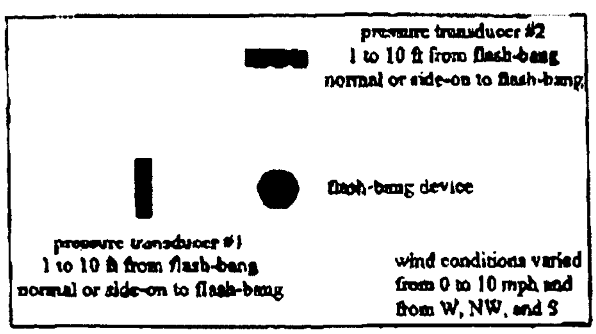


Figure 8. Experimental setup for pressure measurements of a next-generation flash-bang device.

The overpressure was measured at distances from one to ten feet from the device. We oriented the pressure transducers to measure the total (reflected) as well as side-on overpressure. A pressure trace from these preliminary tests is shown in Figure 9. As was seen in Figure 3, the Mk141 produces a shock wave with a rapid ("instantaneous") rise to the peak pressure and an exponential decay. The pressure curve of the next-generation flash-bang device is markedly different. The pressure rise is much more gradual and the peak pressure is significantly lower. When the next-generation flash-bang device functions, a combustion wave rather than a detonation wave proceeds through the fuel-air mixture.

Figure 10 shows several stills from a videotape of one of these proof-of-concept test.

CONCLUSION

We have demonstrated proof-of-concept of a next-generation flash-bang diversionary device. This new design has many advantages over existing flash-bang devices, including less potential for serious injury and fatalities, increased safety from inadvertent initiation, fewer storage and transportation restrictions, lower smoke production, and field-adjustable output.

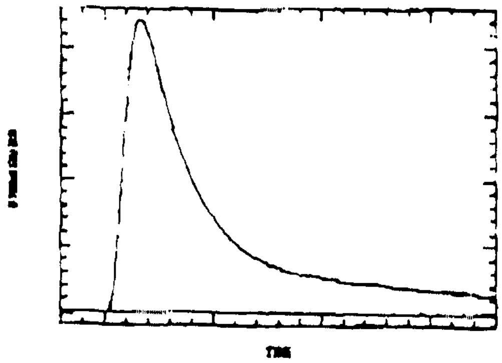


Figure 9. Typical pressure vs time curve from preliminary next-generation flash-bang experiments.

The next step will be to develop a prototype device.

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The authors would like to thank those who assisted in the development of this paper. Bob Benham and Ben Duggins helped greatly in the interpretation of the pressure data and in designing the test configurations. Marc Hagan and Ed Mulligan provided excellent technical support.

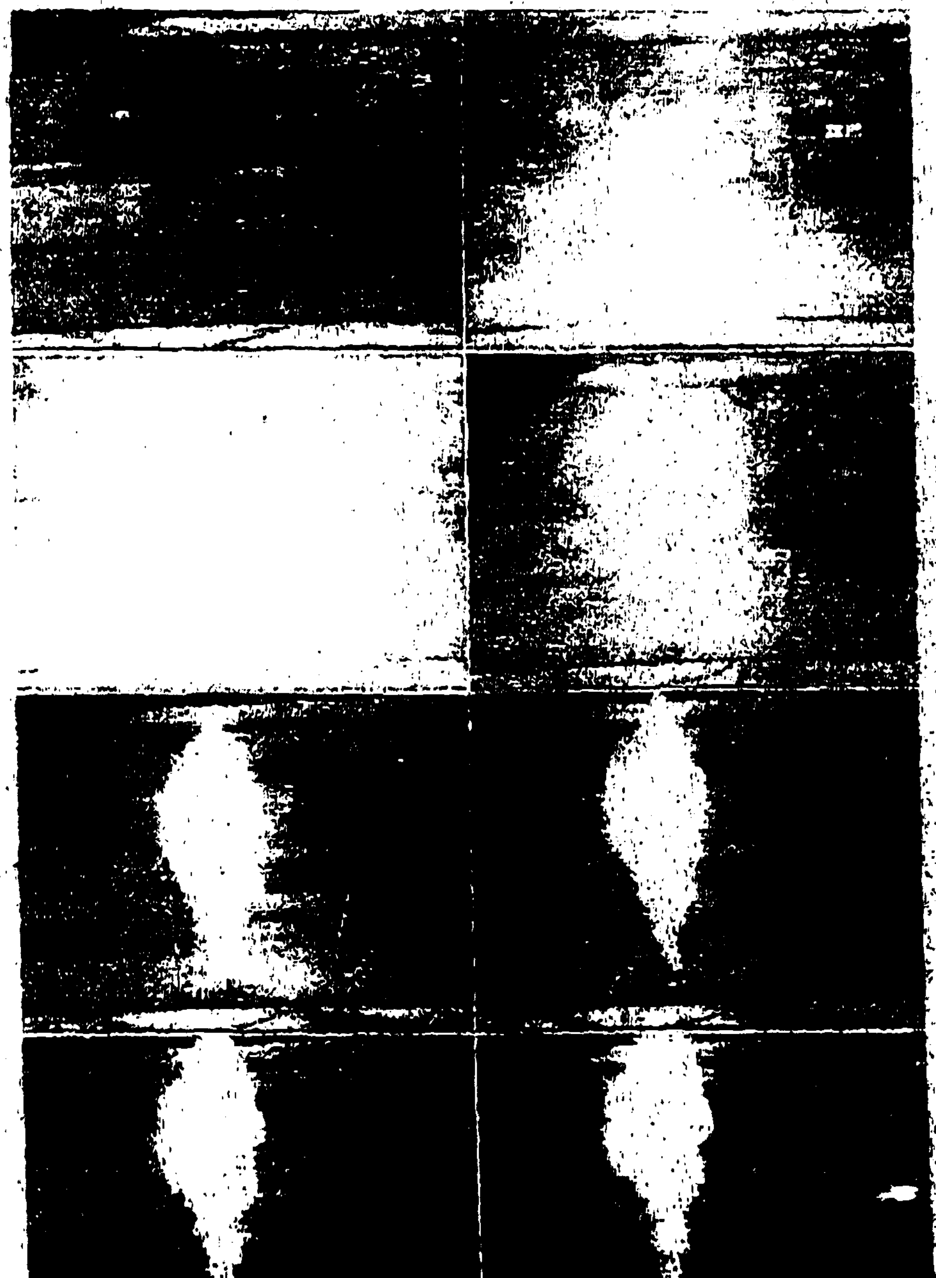

Figure 10. Sequence of eight stills taken from a videotape of one of the preliminary next-generation flash-bang experiments.

EYE-SAFE LASER ILLUMINATORS AS NON-LETHAL WEAPONS

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ABSTRACT

In the present domestic and world political climate, civilian and military forces are often faced with situations requiring less-than-lethal response options. Low-energy, eye-safe laser illuminators have been shown to be effective, non-lethal weapons for a variety of law enforcement and other-than-war military applications. Through the effects of illumination, glare, and psychological impact; lasers can provide unequivocal warning, threat assessment based on reaction to the warning, hesitation, distraction, and reductions in combat and functional effectiveness. This paper discusses three system concepts developed by Science and Engineering Associates, Inc.: a laser flashlight, a laser adjunct to closed-circuit television security systems (fixed or mobile), and a laser police baton. These concepts have been designed, tested, and are production ready.

INTRODUCTION

The fundamental purpose of non-lethal weapons is to offer military and law enforcement personnel response options for situations in which the use of potentially lethal options, such as firearms, are not appropriate at the time. Such situations range from apprehending hostile law breakers to rescuing hostages from terrorists. The need to delay or avoid lethal responses is particularly problematic to military forces engaged in peacekeeping or humanitarian missions in the midst of opposition. Premature response with firearms in these situations often has international ramifications and can escalate into armed conflict. In civilian law enforcement scenarios the consequences of inappropriately severe responses may not be as far-reaching, but on a local scale are nonetheless important. Injury or death of bystanders and even the criminals themselves often results in multi-million dollar lawsuits and negative impact on police department - community relations. Non-lethal weapons can prevent such escalation and thereby significantly reduce the chance of injury or death in these situations.

Non-lethal weapons themselves cover a spectrum of severity in terms of their effect on adversaries and potential for causing injury or even death. Options at the "soft" end of this spectrum include pepper sprays and fired nets, which have little probability of causing permanent harm. At the other end of the spectrum are options such as sticky foams and rubber rounds which, although capable of incapacitating a subject, can cause serious injury or death in some situations. This paper presents a new addition to the soft response options – eye-safe laser illuminators – which have been developed by Science and Engineering Associates (SEA) for both military use and law enforcement applications. These devices are covered by U.S. Patent Number 5,685,636.

THE EFFECTIVENESS OF NON-LETHAL LASER ILLUMINATORS

Low-power (100 - 500 mw) laser illuminators can be effective, non-lethal weapons for a variety of applications. Through the effects of illumination, glare, flashblinding and psychological impact, lasers can (1) provide unequivocal warning; (2) create hesitation, delay, distraction; and (3) reduce combat and firearm proficiency. Furthermore, if continuous wave (cw) lasers are used rather than pulsed

lasers, these effects can be created at exposure levels below the maximum allowed by international safety standards.

Laser Safety

The term *eye-safe*, as applied to the laser devices discussed in this paper, means that the devices are designed to illuminate subjects with beam intensities and operational modes that have a very low probably of causing eye injury. The worst-case exposure that subjects will receive is below the Maximum Permissible Exposure specified by international laser safety standards. In fact, it can be said of the SEA lasers discussed in this paper that:

NON-LETHAL LASER ILLUMINATORS ARE AS EYE-SAFE AS THE SUN!

This statement means that, like the sun, eye damage is possible if one stares into the laser illuminator for several seconds or views it through magnifying optics. However, also like the sun, one must overcome the natural reaction to blink and look away and withstand painful discomfort in order to stare at the source long enough to cause injury.

One further point should be made clear with respect to laser devices in general:

LASERS DO NOT BLIND!

Obviously, this statement cannot be true for the highest power lasers, which could burn the skin as well as the eyes. However, for the power levels employed in current and anticipated battlefield laser devices, the statement does hold true. Although pulsed lasers, particularly those with very short-pulses, can and do cause injury to the eye's retina, only a small portion of the retina is involved and the injury usually results in some degree of permanent visual deficit. Patients with diabetic retinopathy often receive dozens of shots from a pulsed laser to seal off bleeding vessels in the retina, yet still retain functional vision. In the more than two-hundred laser accidents involving the eye during the past several years, most were confined to one eye and none resulted in total blindness in that eye. Furthermore, even though the continuous wave lasers used as non-lethal weapons may cause eye injury in very limited circumstances (such as viewing through a rifle scope), this type of injury is more likely to be in the nature of a retinal sunburn with little or no permanent visual deficit

Laser Effects

The first effect that is usually employed is illumination of the subject's body with the laser beam. The laser beam is a bright red, well-defined circle generally one to two feet in diameter (depending on the range) with a distinct "laser" character due to the optical coherence of laser light. Besides the "laser" look and the red beam (which signifies **STOP!** or **DANGER!** in any language), this beam differs from a flashlight beam in one other key feature: *it can illuminate subjects at ranges exceeding 500 meters at night!* When this beam falls on an adversaries chest, he or she clearly realizes that they have been seen and may have a firearm trained on them. When laser illuminators developed by SEA were employed in Operation United Shield, the U.S. withdrawal from Somalia, simple illumination of armed adversaries was 100% effective. In all cases, the subjects dropped their weapons, surrendered, or fled.

The next level of laser effect is glare and flashblinding. These effects are experienced when one looks at the sun briefly, or catches its reflection from a car window or chrome bumper. Glare can be described as "visual jamming": the light is so bright that it obscures one's vision partially or completely while the light is shining in the eye. Flashblinding, on the other hand, remains after the light is no longer shining in the eyes. This effect causes the "spots before your eyes" after a flash photograph has been taken. Although flashblinding does cause some temporary visual impairment for several seconds after exposure, it is not generally as severe as that caused by glare. Either of these effects, however, is sufficient to reduce an adversary's ability to aim a firearm or effectively engage in other combat actions.

In addition to the above physical effects, laser illuminators can have significant psychological impact, as evidenced by the response of the Somalian adversaries mentioned above. Specific psychological responses include fear, hesitation, and delay. These responses are particularly useful in applications such as drug raids, hostage rescues, dog release against an adversary, and prison cell extractions, where a few seconds advantage is sufficient to overcome the opposition.

Non-lethal laser illuminators can be effective for many applications and scenarios. However, it is important to understand their limitations as well. These devices are more effective at longer ranges in reduced light situations. The darker it is, the better they work. A device that causes glare at 150 meters at night may only be effective at 50 meters in bright daylight. Illumination is even more limited by bright ambient light. A laser that can produce a clearly visible spot out to 500 meters in the dark may only produce a visible spot out to 50 meters during the day. However, in both situations, the laser far outperforms a conventional flashlight or spotlight.

One final limitation of laser non-lethal weapons, which is contrary to some of the fictional accounts of their use, is that these devices do not incapacitate an adversary. An adversary will experience discomfort from the bright light and be forced to look away, but they will not be "stunned" or drop to the ground. On the other hand, they will not be inclined to look or move in the direction of the laser after the first exposure.

SEA LASER DEVICES

For the past ten years, SEA has been involved in analysis, modeling, development, and testing of several eye-safe laser illuminator systems. The first of these is the grenade shell illuminator, developed jointly with the Air Force Weapons Laboratory and the Defense Nuclear Agency (DNA) from 1990 to 1993. After successful field testing this device, now called the Saber 203 system, entered the acquisition phase as an engineering manufacturing development program directed by the Air Force Electronic Systems Center. Current plans call for SEA to begin producing operational systems in early FY 2000.

Over the past year, SEA has employed the technology advancements and technical expertise derived from the early DNA research and the Saber 203 program to develop three additional laser systems for military and civilian law enforcement: (1) the laser flashlight, (2) the laser police baton, and (3) the surveillance camera/laser system. At the same time, SEA developed a business plan to manufacture and market these devices starting in mid-1998. The following sections describe each of these devices and their use.

Laser Flashlight

Although the production version is undergoing final design changes, the current SEA laser flashlight prototype is similar in appearance to a conventional police flashlight, as seen in Figure 1. It is powered by two lithium D-cell batteries and is switched on and off with a pushbutton. The beam spread can be adjusted between narrow angle for long-range illumination and wide angle for area coverage at shorter ranges. The advantages of the laser flashlight in the narrow beam mode over a conventional 5-cell flashlight in terms of effective range is evident from the graphs of Figure 2.

Figure 1. The prototype of SEA laser flashlight is similar to a conventional police flashlight in form and function.

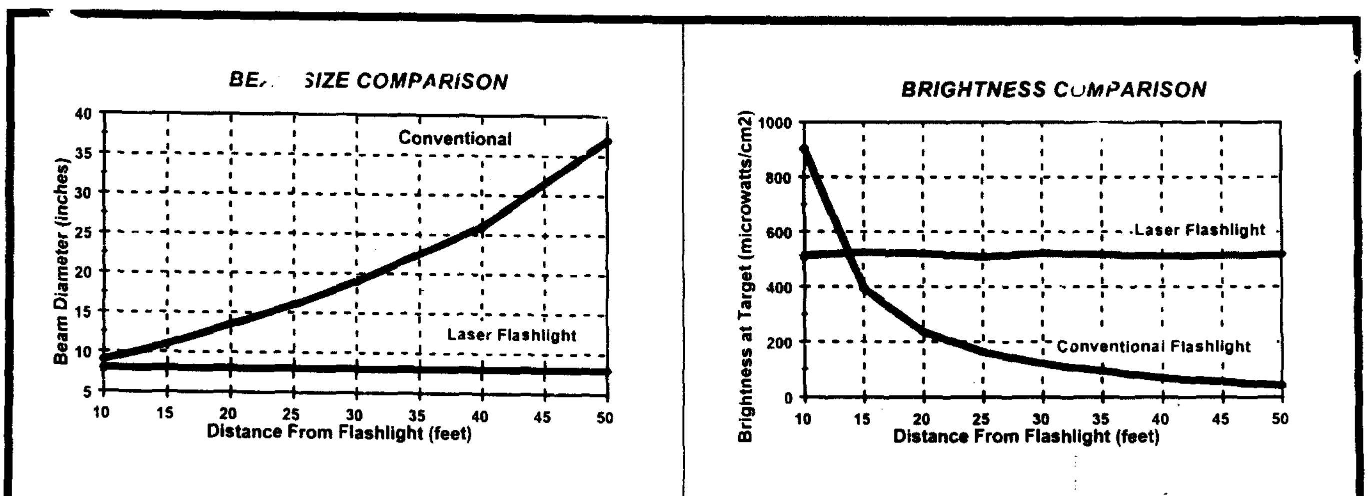

Figure 2. Comparison of conventional police-type flashlight with the SEA laser flashlight.

consuming. This gives security forces time to respond and apprehend the intruder before he can complete his mission and escape. Figure 4 illustrates this new improved system.

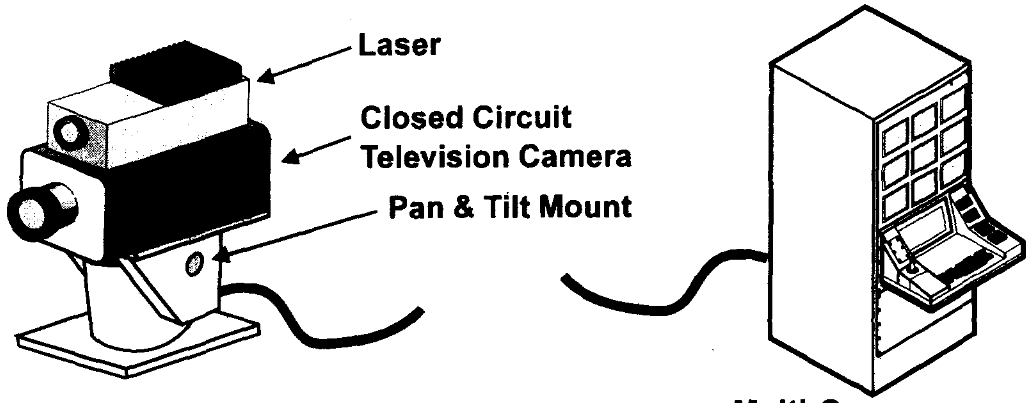

Figure 4. The present SEA design for the surveillance camera/laser system is based on the latest technology available.

POTENTIAL LAW ENFORCEMENT APPLICATIONS FOR NON-LETHAL LASERS

Low-energy lasers used as non-lethal weapons can contribute to success in several law enforcement and corrections applications for a variety of local, state, and federal agencies. Figure 5 illustrates this point with a Laser Concept/User/Applications Matrix. In the center of the matrix are listed five potential using agencies: (1) routine law enforcement at municipal and state levels; (2) special law enforcement operations such as SWAT teams and riot-control forces; (3) U.S. Drug Enforcement Agency and Alcohol Tobacco and Firearms agents; (4) the U.S. Border Patrol and Coast Guard; and (5) corrections institutions at the local, state, and federal levels. In the left wing of the matrix, the four SEA non-lethal laser illuminator devices are shown with check marks to indicate which agencies would be likely to use each concept. In the right wing of the matrix, five application areas are listed, again with check marks indicating the appropriate using agency. These six application areas are described below.

Illuminate/Designate

In almost any situation involving potential conflict, the ability to illuminate and designate at ranges out to 500 meters or more can be a valuable asset. All four of the laser concepts can be very useful as an illuminator or designator. The laser flashlight and surveillance camera/laser (designated CCTV in the figure) are especially good for this application area because, with an adjustable focus capability, they can produce a nearly collimated (parallel) beam of light with a spot diameter of less than a foot at 100 yards range. Besides use directly against subjects, the lasers can be used to illuminate shadowed areas day or night, or designate the location of a hiding suspect. They can also be used to designate buildings, objects, boats, and automobiles, or point out approach routes to the target for maneuvering officers.

Warn

Any of these laser concepts will provide an unequivocal, language-independent warning to an adversary. A subject's reaction to a laser warning can also provide threat assessment. The intent and motivation of the subject can be assessed based on whether the subject surrenders, retreats, continues to advance, or raises a weapon in response to the warning. The anticipated outcomes in most cases are those observed in Somalia: surrender, find cover, or flee. In any of these cases, the likelihood of physical or armed conflict will be reduced.

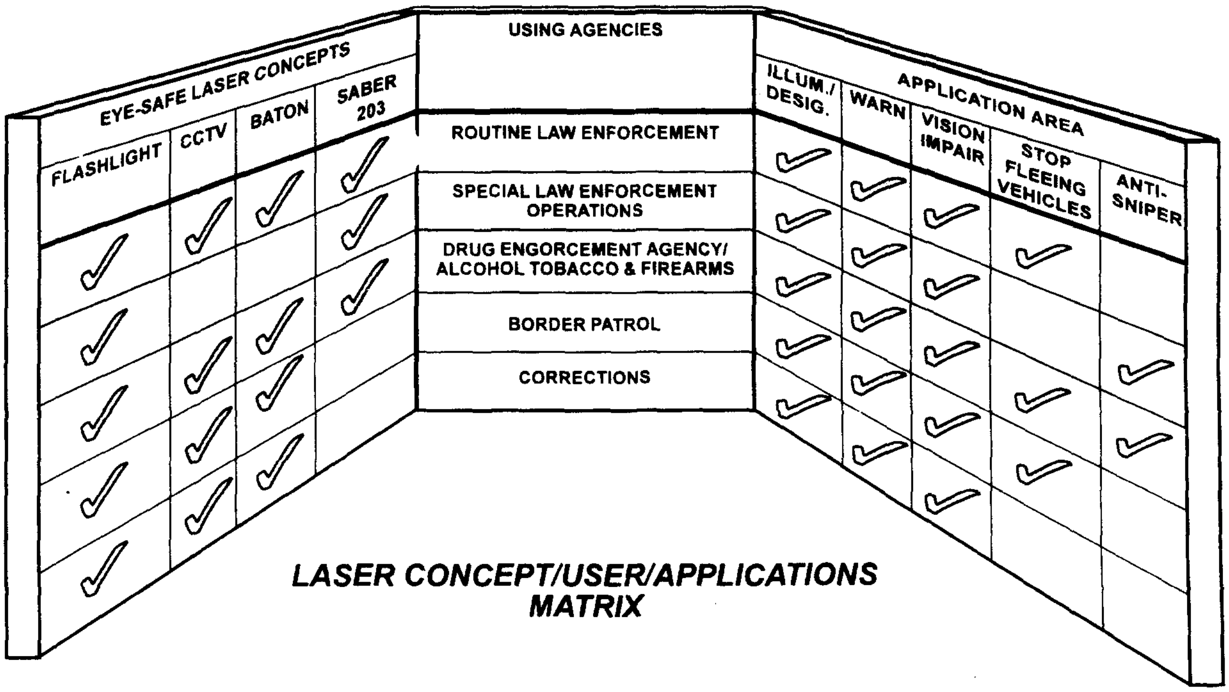

Figure 5. This matrix shows which laser concepts and application areas are likely to be of greatest interest to four types of using agencies.

Impair Vision

If these laser devices are shined in an adversary's eyes, their ability to see is temporarily impaired. If a police officer is holding the flashlight or baton laser, a subject cannot see if the officer is behind cover, armed, or is accompanied by other officers. At night, illuminating a subject's face or chest causes the eye pupils to constrict and makes it very difficult for him or her to run or accurately aim a firearm. Corrections applications in this area include highlighting prisoners in the yard, installing surveillance camera/lasers in critical corridors and gates for riot control, and impairing a prisoner's vision during a cell extraction. The U.S. Border Patrol could use the laser flashlight to impair the vision and slow down fleeing illegal aliens. They currently do this with conventional flashlights, but the range is very limited compared to a laser flashlight. DEA, ATF, U.S Coast Guard, and SWAT forces could use the laser flashlight to impair adversaries vision at long ranges as well as to create distraction and psychological impact.

Stop Fleeing Vehicles

During operational scenario tests of military laser systems by SEA, it was demonstrated that lasers can very effectively obscure a driver's vision when shined on the windshield. There is no need for the laser beam to be directly in the driver's eyes because the scattered light from dirt and pits on the windshield will constrict the pupils sufficiently to prevent the driver from seeing beyond several meters at night, even with the vehicle headlights on high beam. For routine law enforcement use, a helicopter would be the best platform to gain frontal access to the windshield of a fleeing vehicle. The laser could be turned on when the vehicle has slowed down for a turn or is in a situation where the chance for collateral damage is minimal. The Border Patrol could place a CCTV laser a short distance inside border crossings and illuminate the windshield of "gate crashers" before they picked up sufficient speed to be a hazard.

Anti-Sniper

Lasers provide three benefits in the anti-sniper application area. First, they can be used for identifying possible locations of snipers because rifle scopes, as well as other magnifying optics, produce a bright glint return when illuminated by a laser. Secondly, lasers can warn a suspected sniper that he has been spotted and distract him from his mission. If the suspect is not really a sniper, there is no harm done. Finally, if the laser is located within the field of view of the rifle scope when the sniper is looking through it, his vision will be significantly impaired for several seconds due to flashblinding. Furthermore, he will be very hesitant to look through the scope again. Based on recent incidents, these capabilities would be very useful to DEA and ATF agents, as well as SWAT teams at all law enforcement levels.

CONCLUSION

Laser illuminator devices can be used very effectively as non-lethal weapons in a wide variety of military and law enforcement applications. Although these devices are at the soft end of the non-lethal spectrum, they have a very low probability of causing injury to adversaries or innocent bystanders. The variety of laser designs available from SEA allows different users to select the system that best matches their operational needs.

Battlefield Optical Surveillance System (BOSS) -- A HMMWV Mounted System for Non-Lethal Point Defense[a]

W.T. Cooley[1], Trevor Davis[1] and John Kelly[2]

I. INTRODUCTION

As the United States Armed Forces are increasingly asked to control world conflict through humanitarian and peacekeeping missions, nonlethal alternatives for applying force have spurred technologist to identify new methods for engaging potential adversaries. One promising technology comes from advancements in high power (1 to 10 watts) semiconductor lasers, lead by the United States Air Force Research Laboratory, Phillips Research Site. Semiconductor lasers have been fabricated to produce "high power" over the wavelength range 650 – 1550 nm for a variety of applications. The use of semiconductor lasers to illuminate potential adversaries was field tested during operation United Shield in Somolia in 1995. This deployment demonstrated two prototype visible illuminators – the Saber 203, and a diode-pumped, doubled Nd:YAG green laser, in addition to a fiber coupled near infrared (IR) illuminator system. The success of using semiconductor lasers as nonlethal weapons to detect, designate, and deter is the impetus for the Battlefield Optical Surveillance System (BOSS). This paper will present motivation for laser illumination systems, describe the BOSS in detail, present a notional operation scenario, provide laser eye-safety considerations and discuss the tested capability of the BOSS.

II. MOTIVATION

Passive surveillance techniques in the near-IR (700 – 1000 nm) via "night vision" and silicon based detectors, and far IR (8 –12 μm) via thermal cameras that typically use HgCdTe detectors (also known as "forward looking infrared" or "FLIR"), have been used by the military and law enforcement since their introduction. Both technologies compliment each other but are limited under some conditions. One such condition is during very low light. Although the gain on a night vision tube is typically 10^4, if the light is extremely low, the system is marginally effective.

One method to circumvent this shortcoming is to provide active illumination. Using semiconductor lasers, operators can illuminate in the near-IR or the visible depending on the need to operate covertly. Operation in the infrared allows the operator to remain completely covert to troops without night vision equipment, while visible illumination lets the targeted individual know that they have been spotted and are potentially facing a lethal response.

Use of visible lasers enables interaction with an adversary well outside small arms range, which provides a significantly safer environment for friendly troops. It also allows the adversary to be influenced without escalating the situation to lethal force. Jane's

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[a] This paper has been approved for public release by AFRL

[1] AFRL/DELL, 3550 Aberdeen Ave. SE, Kirtland AFB NM 87117

[2] Boeing Corporation, Albuquerque NM

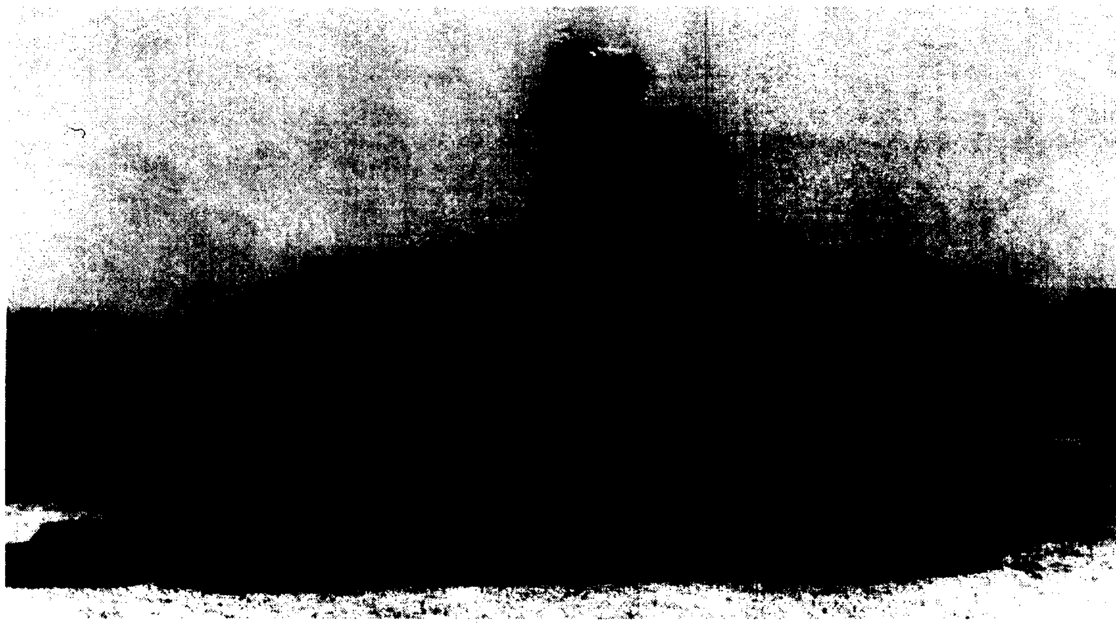

FIGURE 1

Defense weekly described the results that occurred with the use of a visible laser, the Saber 203, during the final withdrawal out of Somalia of UNITED SHIELD.

> "A Marine used the Saber 203 to "Light up" one member in the center of a hostile crowd in an effort to avoid lethal exchange when an armed Somali mob approached a US position. Seconds after the bright red pulse began to appear on the man's chest the mob had dispersed, leaving the "targeted" Somali standing alone."[3]

Visibly designating a potential adversary makes the situation personal for the illuminated individual and the laser removes anonymity and places responsibility for the escalation on the adversary's actions.[4] Lessons learned in Mogadishu regarding application of both visible and infrared illuminator systems led to the second-generation integrated platform, BOSS shown in Figure 1.

The BOSS system was developed with a number of different goals. First, a completely self contained, armored, mobile platform was needed to expand the employment tactics of lasers in combat. As a result, BOSS development was focused on creating a system that employed all the capabilities, and lessons learned, of the units initially deployed to Somalia but on a platform that was capable of rapid deployment and use with mobile units. Secondly, a system with greater power and range was needed to create an even greater standoff distance for friendly troops. With this greater power, however, came the need to properly evaluate and control eye safety issues. Extreme

[3] "Less-Than-Lethal Weapons", Jane's Defense Weekly, 17 July 1996

[4] "Tactical Deployments of Lasers Into Low Intensity Conflicts" 96 IRIS Symposium

importance was placed on making an effective but safe system. Finally, new capabilities were to be designed into the BOSS that included sniper detection through Optical Augmentation. Optical Augmentation is the "cat-eye effect" or retroreflection that is a consequence of using active illumination. An experimental effort at the Air Force Research Laboratory, Phillips Research Site, has found that different optical systems will produce very distinct optical augmentation signals[5]. The addition of optical augmentation recognition adds yet another facet of performance for BOSS operators.

III. SYSTEM DESCRIPTION

The imaging system consists of two FLIR Systems Inc. gimbals mounted on top of a hard top Highly Mobile Multi-Wheeled Vehicle (HMMWV), shown in Figure 2. One contains an 8-12 um FLIR and the other contains a long range LLTV (a night vision tube coupled with a camera is often referred to as a low light television or LLTV) camera system and two laser collimating lens. The LLTV gimbal is mounted above and behind the FLIR to give them the maximum field of view possible. There are three lasers built and integrated by Boeing located off gimbal in the rear of the HMMWV. The light is piped into the gimbal via fiber-optic cables. Both cameras can be viewed on two monitors mounted in front of the right rear seat shown in Figure 3.

The system is powered by a bank of lead acid batteries with a 3kw generator used for charging.

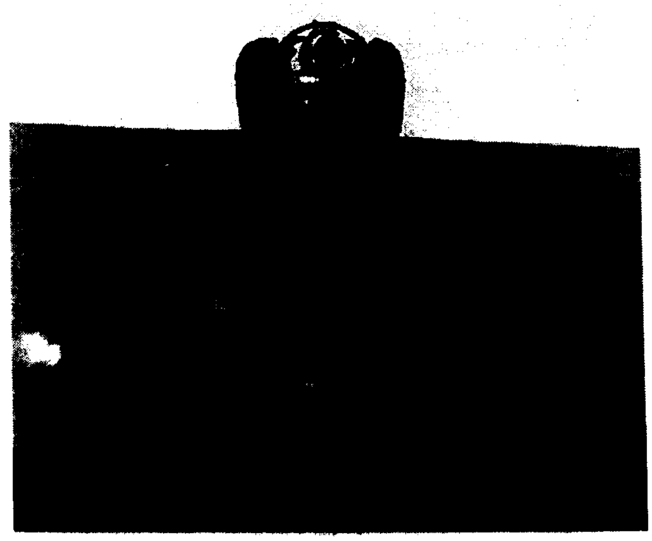

FIGURE 2

Boss Gimbal System

FLIR - The FLIR is an off the shelf FSI Safire cooled 8-12 μm imager. The FLIR system consists of the gimbal, control electronics box, hand control, and monitor. The

[5] S.Z. Peplinski and C.D. Lindstrom, "Non-Lethal Laser System for Sniper Detection via Optical Augmentation" NonLethal Defense III, 1998.

FLIR imager has two fields-of-view(FOV). The wide FOV is 28 x 16.8 degrees and the narrow FOV is 5 x 3 degrees. The imager is manipulated via a joystick on the hand control unit. It also has auto gain, video zoom, and some image processing.

LLTV - The second gimbal was purchased from FLIR Systems and the payload was assembled in-house from a combination of in-house fabricated and off the shelf components. The pointing and aiming controls and associated electronics for this gimbal are similar to the FLIR. The payload consists of a LLTV imager, two laser collimators, fiber-optic cables, and interface electronics. The LLTV imager and laser collimator lenses are mounted on a custom ring. The LLTV imager is centered in the upper portion of the ring and the laser collimator lenses are mounted below symmetrically. The controls for these components have been completely integrated into the FSI hand controller.

The LLTV imager is a combination CCD camera, Gen III intensifier, and 1000 mm zoom lens. The camera is a 1.5" square Sony CCD with a lux rating of .05 lux. The intensifier is a Litton 2400 Auto Day/Night CCTV Sensor. It has the ability in high ambient light conditions to switch out the intensifier tube and insert a relay lens so that a non- intensified image can be viewed. A light sensor allows this to happen automatically or there is a manual override to force it. The 1000 mm zoom lens is optimized for 800 nm light. It is continuously variable over a 500mm range and has a motorized doubler that can be remotely switched in.

The laser collimators are 65mm Rainbow motorized TV zoom lenses. A SMA to C-mount adapter allows the laser fiber to be mated to the lens. The zoom function of the lens allows the laser spot size to be varied. These lenses were selected because they were inexpensive and off-the-shelf technology.

Lasers

The three wavelengths available on the BOSS are 532nm, 670nm, and 810nm. The lasers can all be controlled from the front panel. They are all located off gimbal in the rear of the HMMWV. The light is piped to the gimbal via a 600um .37 NA fiber-optic cable. The lasers can all be remotely operated from the front panel.

NIR Laser - The near infrared laser(NIR) produces 810 nm light. It is a 20 watt GaAlAs diode laser bar that is fiber coupled. Losses associated with the fiber coupling cut power to 12 watts maximum at collimating lens. It is packaged along with power supplies, control electronics, and temperature controls in a 10" x 10" x 12" custom enclosure.

RED Laser - The 670 nm laser is a 3 watt GaAlAs laser. The power at the collimating lens is reduced to 1.5 watts due fiber coupling losses. It is packaged like the NIR laser.

Green Laser - The 532 nm laser is a diode pumped doubled Nd:YVO4 3 watt solid state laser made by Laser Power Corporation. The laser is fiber coupled which cuts the power to 1.5 watts at the collimating lens. It has been packaged into a larger

enclosure to allow for a greater temperature range of operation, remote control, and fiber coupling.

FIGURE 3

IV. OPERATION SCENARIO

The BOSS has several applicable missions including physical security, surveillance outpost, special operations, and law enforcement. The suite of equipment on board enable a progression of surveillance systems in addition to providing the user with the nonleathal capability that was found to be effective during Operation United Shield. Notionally, the 8 –12 μm camera is initially used for broad area passive surveillance. If the operator needs a closer look at potential targets, the FLIR can zoom in with a greater magnification. The near-IR spectral images can be viewed by slaving the CCD camera with night vision tube to the field of view of the FLIR. If the ambient light conditions are very low, or if the user wishes to designate the target for night vision equipped friendly troops, he can illuminate the target with the near-IR laser. The beam divergence is easily controlled to either operate with a large beam divergence for broad area operation, or a narrower beam divergence for target designation. Depending on the threat level, BOSS can then operate as a nonlethal weapon system by illuminating a potential adversary overtly by using one of the visible lasers on board.

Another relevant mission for BOSS is sniper detection. The operator may also use the active illumination capability to search for optical components in the field of view by exploiting the optical return or optical augmentation (OA) characteristics of optical components. The principles of OA are described in detail elsewhere.

V. LASER EYE-SAFETY

Laser eye safety standards exposure are outlined by ANSI-Z136.1-1993 which draw upon a significant number of experimental tests. Because all three lasers on the BOSS are continuous wave (cw) rather than pulsed systems, the ANSI standard is straightforward to understand. For visible lasers the "blink response time" is assumed to be 0.25 sec, thus for the green 532nm and the red 670nm, the maximum permissible exposure (MPE) is 2.55 mW/cm^2. In the case of the near-IR laser, the MPE is modified by a coefficient, referred to as C_A by ANSI, which accounts for the retina's decreased absorption in the near IR. The near-IR laser used in the BOSS system is at 808 nm,

which according to ANSI increases the MPE by 1.644 times over the visible MPE. The blink response time for invisible radiation, including the IR, is simply the average time between blinks, which according to ANSI is 10 sec. The potential for increased retinal exposure is accounted for in ANSI by the relation $t^{1/4}$, where "t" is the exposure duration. Thus, the MPE for IR radiation is multiplied by $(1/40)^{1/4} = 0.398$ resulting in the MPE for our near IR laser is MPE(808nm) = 1.664 mW/cm^2.

Given the MPE, eye safety consideration now becomes a function of beam characteristics and geometry. One important beam characteristic is the homogeneity of the beam profile. Any "hot-spots" in the beam will dictate the total laser power as driven by eye safety considerations. Because the lasers are fiber coupled via 600 μm multi-mode fibers from inside the HMMWV up to the exit optic on the gimbal, the number of modes in the fiber drives the beam quality and homogeneity. The fibers used in the BOSS support well over 10^4 modes for each wavelength resulting in poor beam quality, a wave front that is no longer in phase, and excellent homogeneity.

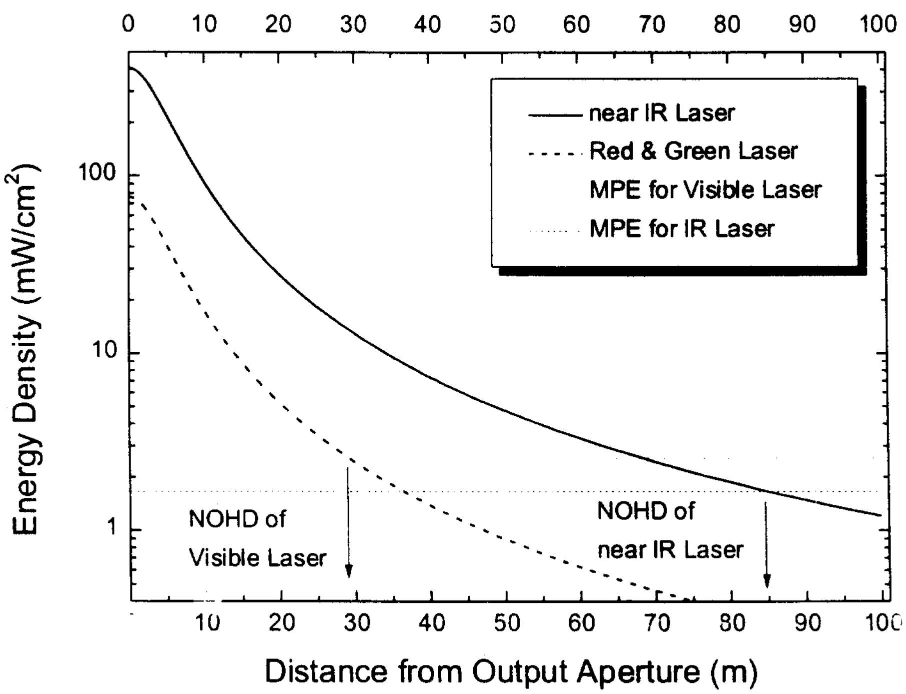

FIGURE 4

The maximum power possible from the near-IR, 670nm, and 532nm lasers are 8 watts, 1.5 watts, and 1.5 watts respectively. The exit apertures for the lasers are each 2 inches. The smallest divergence we are capable of with the 600 μm fiber and a 65 mm focal length lens is 10 m diameter spot at 1 km or approximately 10 mrad. Given this divergence, the nominal ocular hazard distance (NOHD) as defined by ANSI for the 532nm, 670nm and 808nm lasers are 29, 29, and 85 meters respectively. In operation, the

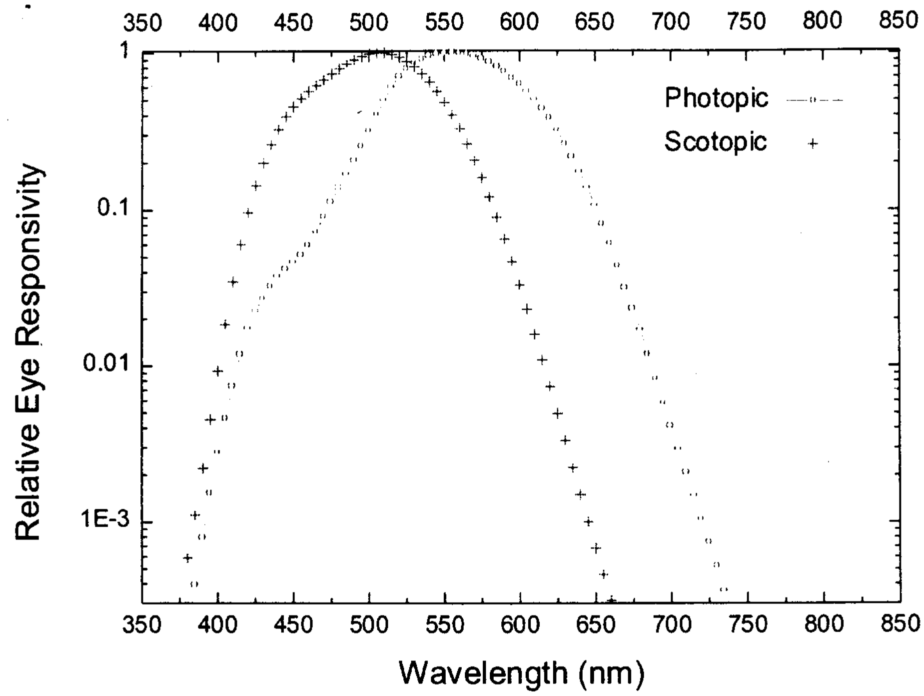

FIGURE 5

BOSS minimum engagement range is 100 meters, thus insuring compliance with ANSI eye safety guidelines. A plot of the optical intensity as a function of distance is shown in Figure 4, along with the MPE levels for the visible and IR laser wavelengths.

The ANSI standard guidelines were developed for inadvertent or unintentional exposure to lasers. At the time of this paper, no clear guidance exists for intentional exposure by nonlethal laser illuminator weapons. The only potential modification for intentional exposure versus unintentional is in the amount of time an individual would likely look directly into the laser without moving the eye. It is important to bear in mind three things with regard to this distinction. First, the cumulative eye safety consideration associated with exposure duration is only weakly related, given by $(\text{time})^{1/4}$. Second, the individual being exposed must maintain a motionless eye for cumulative effects to potentially cause any damage. Third, the calculations presented here are for the worst possible case with regard to laser power and beam geometry.

It is also worth noting at this point the sensitivity of the eye as a function of wavelength for both light adapted, photopic, and dark adapted, scotopic, vision. This information is readily available on the World Wide Web at http://cvision.ucsd.edu and is plotted in Figure 5. The motivation to use 532 nm over 670 nm for nonlethal engagement is readily apparent from this plot. For scotopic vision, the eye is over 5000 times more sensitive to 530nm than to 670nm, and 25 times more sensitive for photopic vision.

VI. CAPABILITY

The combination of active LLTV and FLIR give the BOSS the ability detect, assess, and deter possible threats at a standoff range of greater then 1 km in any ambient lighting conditions. The FLIR can readily detect heat signatures, under typical conditions, the size of a man at 1 km in wide FOV. It may be possible for hostile personnel to hide behind and in obstructions to hide their thermal signature, but if they use any optics to observe the BOSS's position, BOSS operators using any of the three lasers can detect them. The operator of the BOSS will see a bright flash on the monitor screen and know immediately that there is a sophisticated threat. Once the threat is detected the operator can then zoom in with the LLTV to assess the level of reaction required. The visible lasers can then be activated to designate the target. This beam will immediately communicate to friendly forces the location of the threat and if warranted, lethal force can be applied.

VII. SUMMARY

In the past, American troops had little choice for nonlethal detection, deterrence, and designation – not so anymore. With the technological advancements in high power semiconductor laser technology, lead by the United States Air Force Research Laboratory, Phillips Research Site, American soldiers now have the capability to take nonlethal action in situations that before were only possible through lethal means. As a result of today's warfighter's needs and the roles America will ask the armed forces to play, development of a comprehensive system for night time surveillance and deterrence is vital to successful control of the battlefield – BOSS is that system. This effort was funded by DARPA – Counter Sniper Office.

Injury Risk Assessment of Single Target and Area Fire Less Lethal Munitions

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ABSTRACT

In the midst of downsizing and budget cuts, the United States Military faces the difficult task of remaining an elite lethal fighting unit while acting as a global police force. In places like Haiti, Somalia, and now Bosnia, the U.S. forces must engage a different type of combatant; unarmed men, women, and children. In order to deal with these types of conflict, the military has turned its focus to non-lethal alternatives. One of these alternatives is specialty impact munitions or kinetic energy rounds. Since each munition is designed for a specific application, a common method of determining a risk of injury related to blunt trauma has to be established. Since these rounds are designed not to penetrate the body, the most applicable means of assessing the potential injury is to determine the severity of blunt trauma. Tests were conducted on the 3-Rib Chest Structure (3-RCS) with an injury criterion developed within the automotive industry to assess blunt thoracic impacts. This criterion called the Viscous Criterion (VC) is dependent on not only the amount of chest deflection but also the rate at which it occurs. These are the two basic components contributing to the severity of injury associated with blunt trauma. The purpose of this study was to evaluate a risk of injury from non-lethal projectiles utilized by the military and law enforcement communities.

INTRODUCTION

The need to control potentially damaging or life threatening situations without the use of lethal force poses a unique challenge to those in authority. A gathering of a large crowd, whether celebrating or protesting, can become a threat to the safety of those involved. In addition to the need to control large crowds, law enforcement officials have also been confronted with individuals that pose a threat to themselves or others. These scenarios often do not warrant the use of lethal force. Therefore, the ballistics industry, as well as the military, has researched and developed products which are often called non-lethal or less-lethal. These products include such devices as chemical irritants, distraction devices and kinetic energy projectiles. In the past several years, the types of less-lethal projectiles, as well as their application, has steadily increased. However, a standard testing method to determine their effectiveness and associated risk of injury has not been developed. One proposed method is presented to assess the trauma associated with blunt impacts to the thoracic region caused by less lethal projectiles.

BACKGROUND

In the midst of downsizing and budget cuts, the United States Military faces the difficult task of remaining an elite lethal fighting unit while acting as a global police force. In conflicts such as the Persian Gulf, the military is called upon to use superior technology to liberate a country under siege. More recently however, the military has been called upon to free individuals from civil unrest, offer famine relief, and keep warring factions apart. In places like Haiti, Somalia, and now Bosnia, the U.S. forces must engage a different type of combatant; unarmed men, women, and children.

In order to deal with these types of conflict, the military has turned its focus to non-lethal alternatives. One of these alternatives is specialty impact munitions or kinetic energy rounds. These munitions include rubber pellets, wood batons, rubber sabots, foam batons, and bean bags. Each munition has a specific application determined by the "knock-down" effectiveness and accuracy of each round. These munitions are not intended to take the place of lethal weapons, but rather offer an alternative prior to the use of lethal force. These munitions defuse aggressive or threatening actions, either through individual blunt force or by promoting area denial.

There are two basic categories of specialty impact munitions available in the 12 gauge or 40 mm weapon systems; single projectile and multiple projectiles. Single projectiles allow the shooter to isolate single targets, such as a "ring-leader" or instigator and generally deliver a greater impact force. The munitions available in the 12 gauge weapon system include the bean bag, fin sabot, single ball, and wood baton. A single bean bag round can be fired out of the M79 or M203 grenade launchers within the 40 mm systems. Multiple projectile munitions, also referred to as area denial munitions, are used for multiple targets such as a crowd line or to promote area denial. Because these munitions contain several projectiles and are less discriminate in their target, they generally deliver a lower impact force. Types of these munitions include rubber pellets shot at two velocities from the 12 gauge and multiple pellets or balls, foam batons, and wood batons shot from the 40 mm weapon systems.

Although varying in the desired effects, the common objective of these munitions is to exert enough force to ensure compliance. In order to maintain a non-lethal outcome, it is necessary to minimize this force. This must be done without jeopardizing the safety of the soldiers and that of the combatants. To obtain this goal, these munitions will have an inherent potential for causing injury, but with a low probability of causing serious physical harm. The impact of the projectile, along with the associated pain, work together to deter the individual from the unwanted aggressive action. Because of the dynamics of how these munitions function, a method of determining a threshold of blunt injury needs to be established.

One industry where the incidence and consequence of blunt thoracic trauma has been extensively investigated is the automotive industry (1,2). In a set of papers authored by Kroell (4,5), the amount of compression was investigated as a means for assessing blunt thoracic chest injuries. Kroell demonstrated that rib fractures occurred when a 20% compression was induced by a impact velocity of 5-7 m/s. When the compression reached 40% multiple rib fractures occurred in the cadavers tested. This level of compression was associated with a 50-50 chance of sustaining severe chest injury (2).

In 1985 Viano and Lau (6) developed a new criterion called the Viscous Criterion (VC). The VC has been documented to predict the severity of soft tissue injury and cardio-respiratory dysfunction caused by blunt impacts (2). It is a time dependent product of the velocity of the deformation of the chest (V) and the amount compression (C) (6). The chest compression is defined as the displacement of the chest in relationship to the spine normalized by the initial thickness of the thorax. Thus, this criterion is dependent upon not only the amount of compression, but also the rate at which the compression occurs. As discussed by Kroell et al. (7), both compression and velocity of compression contribute to the severity of injury related to chest impacts. They have also demonstrated that VC is a good predictor of functional injury to the heart

and respiratory system. This functional injury was demonstrated in the form of cardiac arrhythmias.

Studies have also shown (2, 6, 8) that VC is the best indicator for injuries of soft tissues for deformation velocities between 3 and 30 m/s. When the deformation velocity is below 3 m/s , the impact velocity becomes less critical. At these lower velocities, the mechanism of injury is one of a crushing of tissues. When the deformation velocity reaches above 30 m/s, the compression of the tissue becomes insignificant because the mechanism of injury is one of a blast injury.

In an effort to determine the effects of a given impact a biomechanical surrogate is employed. Developed and validated against existing human response data, biomechanical surrogates are commonly called crash test dummies. Instrumentation strategically placed within the surrogate allows for essential data to be coll ted from which the VC and related risk of injury can be calculated. Current surrogates include the Hybrid III for frontal impacts and the BIOSID and EuroSID for lateral impacts.

Recently, a new frontal impact surrogate has been developed known as the 3-Rib Chest Structure (3-RCS). This system was developed because of the need for a portable, low cost system that can be utilized outside of the automotive industry. The field of non-lethal or less-lethal ballistics is one area where this system can be utilized to provide injury data. Utilizing the ribs of the BIOSID, the 3-RCS is designed for the collection of data with low mass, high velocity impacts. Preliminary data was collected to investigate the effectiveness of several different types of non-lethal or less-lethal projectiles utilizing the new 3-RCS.

STUDY DESIGN

Testing was conducted at the Washtenaw Community College (Ypsilanti, MI) firing range. The three-rib structure was placed on a movable chart at the far end of the range at height that allowed for impacts to occur at the center of the sternum. The projectiles were fired from either a 12 gauge shotgun or a 37 mm gas gun at 30 and/or 45 feet based on the specifications of the munitions being tested. The velocities of these projectiles were recorded with an Oehler Research, Inc. Model 35P chronograph placed approximately 20 feet from the desired point of impact.

Several munitions were tested that were considered non-lethal or less-lethal. The basic design of the munitions is similar to that of lethal projectiles. There is a primer at the distal end followed by a propellant charge. Next, varying submunitions are placed between a lower and upper wad. The entire munition is encased in an outer shell. The main difference between lethal and less-lethal munitions is the design of the submunition and amount of propellant. These two variables helped to determine the velocity, range, and impact characteristics of the munitions.

The types of submunitions varied from a single, larger projectile like a bean bag to several smaller projectiles such as rubber balls. The variance in the design of the submunition allowed for the variance in the scenarios for which they were to be utilized; i.e. a single target or area fire. The proximity of the scenario also is a contributing factor as to which munition would be most

effective. Given this reason, the munitions were tested at the two distances of 30 or 45 feet. Some of the munitions were tested at both when their application allowed.

In addition to the velocity of the projectile, the location of each impact was recorded. The three-rib system has a 6" X 9" impact surface made of Ensolite® padding that was 5/8 inch thick and had a known density of 9-10 pounds per cubic foot. The padding was replaced at the beginning of the testing of each new munition. The 6 inch by 9 inch pad was divided into the 9 regions indicated below:

UL	UC	UR
ML	C	MR
LL	LC	LR

During this testing it was felt that the accuracy of the rib deflection is dependent upon where the impact occurred. The center impacts were considered to be the most accurate with a decrease in accuracy occurring as the impacts approached the exterior. Testing conducted at a later date utilizing high speed video confirmed this theory.

One channel of data from the three-rib system was collected by RC Electronics data acquisition system via an A to D board. This input was received from the linear transducer located behind the sternum at the level of the middle rib. This measurement provided the amount displacement as a function of time that occurred within the thoracic. From this measurement, the VC was calculated.

RESULTS/DISCUSSION

The results varied depending upon the type of munitions. Those munitions designed to be utilized for area fire, multiple balls and foam or wood batons, had several smaller projectiles as submunition within their casing. Once fired, these submunitions were designed to disperse outward. Therefore, the amount of kinetic energy each one contained was minimal and was not adequate to cause any rib deflection even if several impacted the target at the same time. Therefore, VC values were not calculated for these munitions.

Refinement of the testing process occurred based on more recent testing where high speed video was also incorporated. The area of shot placement and velocity of chest deflection was utilized as a guideline of acceptance. If an impact occur outside of the 2" X 3" rectangular area surrounding the center it was not considered to be accurate. Additionally, if the chest deflection exceeded 10m/s than the test was also disregarded since this value exceeded the specifications of the transducer.

Those impacts that were considered accurate based on the above criteria were then analyzed. The results of this analysis are presented below:

PROJECTILE TYPE	MASS (gm)	IMPACT VELOCITY (m/s)	CHEST DISPLACEMENT (mm)	IMPACT ENERGY (J)	VC
.60 cal rubber ball	3.7	346	5.00	221.41	.09
.60 cal rubber ball	3.7	326	7.58	197.14	.20
12 ga bean bag	41	94	10.90	180.67	.28
12 ga bean bag	41	92	9.50	174.85	.24
12 ga bean bag	41	98	12.06	195.02	.19
40mm bean bag	100	66	12.70	216.72	.20

Applying the Viscous Criterion to previously published blunt frontal impact data, statistical analysis show that the VC max was highly correlated with the risk of severe injury. There is a very low probability of injury for corresponding low values of VC. Accordingly, with very high values of VC, the probability of injury is essentially 100%. There is a transition zone between these two regions where the probability of injury is proportional to a change in VC (9). The compression criterion indicates that the highest risk of injury occurs at the point of maximum deflection. However, the VC indicates that the highest risk of functional injury occurs at approximately the midpoint, well before the maximum deflection is reached. Because of this, recommended values of viscous tolerance for the chest of VC max are 1.00 m/s and a compression tolerance of 35% (10).

CONCLUSION

Injury due to chest impact is primarily related to the amount of energy absorbed. The viscous response relates to the energy absorbed by rate-dependent processes; the higher the VC, the greater the energy absorbed by the tissue and the greater the risk of injury. Typically, lightweight projectile impacts result in minimal energy transfer to whole body motion. However, understanding the relationship between energy transferred to chest deformation and whole-body motion is a critical factor in comparing experimental results (11). Several theories were explored, including the possibility that the lower ballistic mass transfers less energy to rib deflection and more to accelerating the mass of the chest. However, the exact mechanism for these results remains unclear.

Based on this modeling and on previous research, the ballistics do not appear to be in the range where fatality occurs, which is consistent with actual field use of this munition. However, there are a few limitations that exist with this analysis. The small sample size for the ballistic testing becomes a concern when there is a desire to generalize the results. Further testing has recently been completed and initial findings are consistent with these indications. However, this is not to say that serious injury or death could not result with an impact of less lethal projectiles. In order to minimize this risk of injury, it is essential that these munitions be deployed in a proper manner.

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Development of a Low-cost, Portable Surrogate - The 3-Rib Chest Structure

Cynthia A. Bir, David H. Lyon and David C. Viano

Introduction

Law enforcement and military agencies are increasingly called upon to neutralize potentially life-threatening situations without employing lethal force. As a result, these agencies have experimented with and deployed to varying degrees a number of presumably nonlethal weapons. Resources have been dedicated to advancing nonlethal technology, particularly in the last decade. Manufacturers have increased the available nonlethal arsenal in an effort to provide a spectrum of implements suited to the continuum of scenarios encountered by authorities. Whether confronted with a single distraught individual threatening to take his/her own life, or a large rioting crowd posing an imminent threat to the property and lives of others, authorities are expected to resolve the conflict without imposing excessive force so that a fatal outcome may be averted. However, even limited experience with nonlethal technology has demonstrated that fatalities may still occur (1). As such, a means to evaluate the risk and extent of injury associated with a typical use of nonlethal force is necessary. However, no standard test method currently exists by which to evaluate the probability of a lethal or nonlethal outcome.

Injury Criteria

The automotive industry has extensively explored the effects of blunt trauma (2) in an effort to reduce injuries associated with vehicular accidents. As the research of blunt thoracic impacts has evolved, so have the various injury tolerance criteria associated with these impacts. The first frontal impact tests and standards relied upon a criterion based purely on spinal acceleration. This criterion, labeled the Acceleration Criteria, was solely based on the peak acceleration and stated that it should not exceed 60 g's for longer than a 3 ms period (3). Although the measurement of spinal acceleration is a good measurement of whole body impacts, it was found to be an inaccurate assessment of the deformation of the thoracic cavity. It is primarily useful in determining skeletal injury, therefore, soft tissue injury data is not available with this criterion. However, the criterion is widely used in civilian and military vehicle crash safety assessment.

Studies related to energy-absorbing steering columns conducted by Patrick et al. (4) depended upon the level of force as the sole criterion for injury. Cadavers were used to impact padded load cells in order to determine the forces experienced by the body region of interest. While the Force Criterion contributed to the implementation of this new safety device, it did not accurately characterize all mechanisms of injury associated with blunt thoracic trauma. This was due to the variable nature of the inertial, elastic, and viscous components of the human body on the reaction force developed.

Based on an analysis of cadaver testing, Kroell identified maximum chest compression as an indicator of severity of chest injury (5, 6). Kroell demonstrated that rib fractures occurred when impact velocities of 5-7 m/s induced thorax compression of greater than 20 percent. When the compression reached 40 percent, multiple rib fractures occurred in the cadavers tested. This type of injury would be clinically manifested as flail chest which is considered a life-threatening injury. The Compression

Criteria is a valid injury indicator only if the chest is treated as a rigid body. However, the vital organs within the chest cavity necessitate consideration of the mechanism of soft tissue injuries to provide an accurate indication of thoracic injury.

When examining soft tissue injuries there has been a relationship noted not only to the amount of chest compression but also to the rate of compression (7). In experiments with a constant magnitude of compression, an increase in the velocity of compression led to an increase in the severity of injury. While the Compression Criteria captures the contribution of the magnitude of compression to thoracic injury, it does not consider the rate of compression and therefore has a limited range of validity.

The relationship between compression and velocity of compression was further validated as a factor in the causation of blunt thoracic injury by Kroell et al. (8). Viano and Lau (9) demonstrated that the injury tolerance of soft tissues was related to a viscous response. Within their testing regimen, impacts were conducted on anesthetized rabbits with impact velocities ranging from 5-22 m/s and maximum thoracic compressions of 4-55 percent. The amount of chest compression (C) is defined as the displacement of the chest in relationship to the spine normalized by the initial thickness of the thorax. This analysis demonstrated that both the compression (C) and the rate a which it occurred (V) should be considered to accurately predict the risk of injury.

These two parameters were brought together in the form of the Viscous Criterion or VC. Logist analysis indicated that the combination of velocity of compression and amount of compression (VC) had a higher predictive ability of injury than either velocity (V) or amount of compression (C) alone. Viano and Lau (15) further validated the Viscous Criterion (VC) with a reanalysis of existing cadaver data. Again it was demonstrated that the maximum Viscous response was highly correlated to the risk of severe soft tissue, internal organ, and functional injury. A tolerance level of a VC max value of 1.00 m/s was established which correlated to a 25% probability of injury for frontal chest impacts. Further testing demonstrated the ability of VC max to predict the probability of heart rupture (11) and correlates with cardiac arrhythmia. Severe liver lacerations were also found to be predicted by VC max (12).

The range of validity of VC max has also been delineated (10, 12). For impacts resulting in velocity of chest deformation between 3 and 30 m/s, VC max is able to predict the risk of injury. When the deformation velocity is below 3 m/s, the injury becomes primarily due to the crushing of tissue such that the Compression Criteria is a more suitable indicator. When the velocity of deformation is above 30 m/s, the injury is predominantly caused by the velocity component. At these higher velocities the injuries are due to a blast mechanism (13).

Biomechanical Surrogates

Even though the human injury tolerance has been established for a given impact and suitable criteria have been developed, each specific impact scenario should be assessed to determine its injury potential. In an effort to reduce the need for extensive animal or cadaver testing, the development

of biomechanical surrogates has been pursued. Once designed and validated, surrogates provide a means for obtaining large amounts of data without the utilization of live animals or cadavers. The first mechanical surrogates were developed by the military to test ejection seats in the late 1960's (14). The need for more accurate and precise data in vehicular crash analyses resulted in a more sophisticated family of surrogates being developed by the automotive industry.

The first family of biomechanical surrogates that most accurately demonstrated human-like chest responses for frontal impacts was the Hybrid III (15). The Hybrid III family of surrogates includes: 5th percentile female, 50th percentile male, 95th percentile male, 6 month old, 3 year old, and 6 year old. Each of these surrogates correlates with the anthropomorphic grouping it represents in relation to its external dimensions and compliance of internal structures. The need for assessment of lateral impacts led to the development of side impact surrogates such as the EuroSid and BIOSid (16).

The validation of biomechanical surrogates has primarily been based on data collected with mechanical impacts to cadavers (17). From these impacts, response corridors were generated:

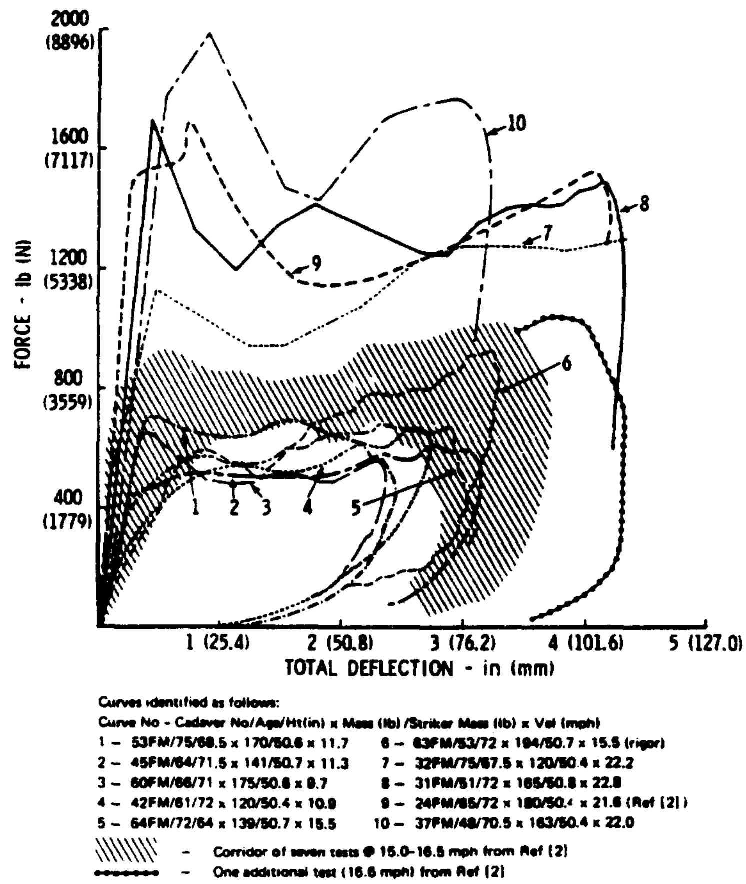

Figure 1: Human response corridors established with high mass, low impact velocity impacts to cadavers. Kroell, C.K., Schneider, D.C. Nahum, A.M. Impact tolerance and response of the human thorax II. SAE 741187 18th Stapp Car Crash Conference, 1974.

These corridors help to establish the biofidelity of the surrogates. The corridors were established with those impact characteristics seen in vehicular collisions, or high mass, low velocity impacts. The velocities of impacts ranged between 5 - 9 m/s and the mass of the impactor varied from 50 - 85 kg. Pendulum impact tests, simulating similar conditions, were then performed on the HybridIII to demonstrate the correlation of its response to that of the cadavers.

Once validated, the surrogates allow an injury risk assessment to be conducted given a blunt impact. Sensors are placed within the surrogate to collect valuable mechanical data. Each of the Hybrid-III systems has a variety of accelerometers and a potentiometer strategically placed to obtain key information. To assess the injuries associated with chest impacts, chest displacement is measured over the time of the impact. From this measurement, VC max can be calculated.

Development of 3-Rib Chest Structure

Based on the advancements in the automotive industry, it would seem logical that the same approach could be taken to establish the risk of injury due to nonlethal munitions. However, the transition from the high mass, low velocity impacts typical in the automotive industry to the low mass, high velocity impacts characteristic of nonlethal projectiles must be critically evaluated and made with caution. The first step is to determine human tolerance criteria. Given that the most severe injuries are occurring with blunt frontal chest impacts, VC max appears to be the most suitable of the criteria developed to date. Because VC max has been validated for chest deformation rates up to 30 m/s, it would appear to be a viable criterion to test.

The next step is to elucidate the type of biomechanical surrogate to employ for the impacts. The HybridIII, since developed and validated for frontal impacts, appears to be the logical choice. However, preliminary testing with this device has revealed inadequacies related to the high velocity impacts of nonlethal projectiles. The sensors within the surrogate and the internal design of the thorax system do not provide the kind of repeatable response needed for these impacts.

When exploring other options, it was noted that the BIOSid ribs were a continuous structure and would provide an adequate loading surface. The Hybrid-III ribs come in two halves which are connected to a leather sternum that is not suitable for projectile impacts. The development of a transducer that could track higher velocities would also provide an option for more accurate tracking of the impact. By combining these two key elements into one structure, the 3 Rib Chest Structure (3-RCS) was created. Three BIOSid ribs were mounted to a spine box opposite the impact side. Damping material on the inside of the rib provided for viscous bending resistance and allowed for the dissipation of energy. Nylon supports were mounted to the sides of the spine box to prohibit gross upward and downward motion of the ribs.

The impact surface was created with a 15.5 cm high and 23 cm wide urethane bibb that tied the three ribs together on the impact side. A padding made of Ensolite7 approximately 5/8 inch thick covered the urethane plate. This padding was chosen for its response characteristics after testing of about 10 pads of different materials. The conductive-plastic position transducer was mounted to the interior

of the middle rib directly behind the urethane bibb so that device displacement could be measured and a VC max calculated.

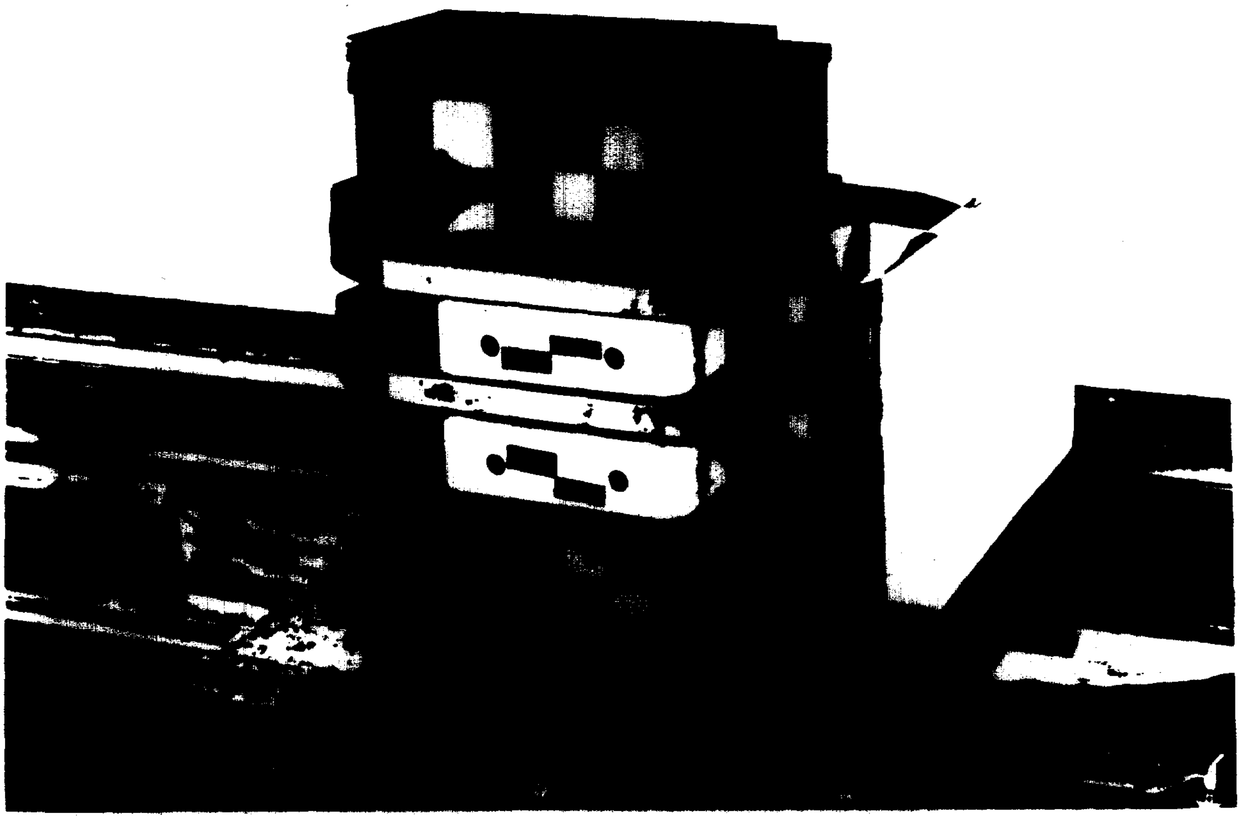

Figure 2: 3-Rib Chest Structure (3-RCS) developed from BIOSid ribs for low mass, high velocity impacts.

Preliminary testing was conducted on a variety of non-lethal munitions. Some general observations were made during testing. For all impacts, the location of shot placement is vital. Currently, the only transducer to record the amount of chest displacement is directly behind the middle rib. By virtue of this design, if one of the other ribs carries the majority of the load transfer, the transducer does not track an accurate amount of actual chest displacement. This is best seen on the high speed video where an impact to the upper or lower rib causes large displacements in the respective rib and minimal displacement in the middle rib. The establishment of the region of acceptance helps to compensate for this problem. However, potentially worthwhile data are lost.

Due to the high velocity at which the impacts occur, the transducer must be able to track higher velocity rib displacement than those seen in automotive impacts. From observing the video and comparing it to the measured displacement, it is noted that the recorded maximum displacement is not always accurate. This is especially true with the higher kinetic energy rounds where the transducer experiences a higher transfer of energy. This energy creates a large spike of noise in the output. By filtering the data the majority of this phenomenon is eliminated. However, not all of the noise can be filtered. Therefore, the guideline of a maximum velocity of $\leq$10m/s for acceptance was established based on the specifications of the transducer.

Another limitation is the transducer specifications and sensitivity of shot placement. If a tracking system could be identified that records higher velocities then this system could be placed on each rib. This would help to eliminate both of these limitations. However, the greatest limitation with this testing system is a lack of established biofidelity. A data set does not currently exist from which human response corridors can be established. The establishment of such a database will allow for a completion validation process to occur.

Conclusions

There is a need that exists in the law enforcement arena to be able to diffuse threatening situations without the use of lethal force. However, before this need is met, there is also a need to determine the lethality of the force employed. Without knowing the injury risk associated with the utilization of non-lethal technology, the deployment of this technology can potentially become a liability. The ability to test the nonlethal projectiles in a controlled environment allows for a thorough assessment to occur prior to utilization in the field. This allows for a higher level of protection for both the officer/agent utilizing the technology as well as the assailant. The validation of the 3-RCS against the human cadaver responses will provide a means for providing this protection. Once validated, virtually all types of nonlethal munitions can then be tested with the device and a percent risk of injury can be determined prior to the utilization of the munition in the field.

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Injury Evaluation Techniques for Non Lethal, Kinetic Energy Munitions

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ABSTRACT

Numerous types of non-penetrating, kinetic energy munitions have been developed and deployed throughout both the military and law enforcement communities. The ability to evaluate the injury potential associated with this class of munitions has presented itself as a novel problem for the scientific community. Although several evaluation methods have been employed, currently there is no widely accepted method for evaluating injury levels resulting from blunt impact derived from nonlethal projectiles. This paper briefly reviews two existing experimental techniques in addition to introducing a third. Data obtained from each of these procedures was collected, for similar impacts, and is offered for comparison.

BACKGROUND

Ballistic Resistance of Police Body Armor

Along with the deployment of soft body armor, for civilian law enforcement, came the requirement to establish a method to evaluate the performance claims of various manufacturers. As an entity under the Department of Justice, the National Institute of Justice (NIJ) is chartered to assist with law enforcement issues at a national level. In response, the NIJ established a consortium of military and medical personnel, with expertise in the areas of wound ballistics and blunt trauma, to collect and correlate all existing data regarding blunt impact injury. The results of this study represented a comprehensive assembly of available animal data and was published as "Body Armor - Blunt Trauma Data".[1] This report also attempted to correlate the identified data using various combinations of parameters. Although no one set of parameters was able to accurately discriminate all data points, a reasonable fit was accomplished using a four parameter model which included; projectile mass (gm), velocity (m/s), diameter (cm), and target mass (kg). This model was then extrapolated from the mass of the target animals to that of a typical adult male (70 kg). Incorporated into the plot of Figure 1 are solid discriminant lines, each having a slope of one, which divide the graph into three regions. The X and Y intercepts for these lines were then determined by data fitting. The three areas; a zone of low lethality, a zone of mixed results, and a zone of high lethality were due to data scatter, a simple live/die outcome, and inconsistencies between the data sets. In addition, dotted lines depicting 40 mm and 80 mm diameter projectiles are included for reference.

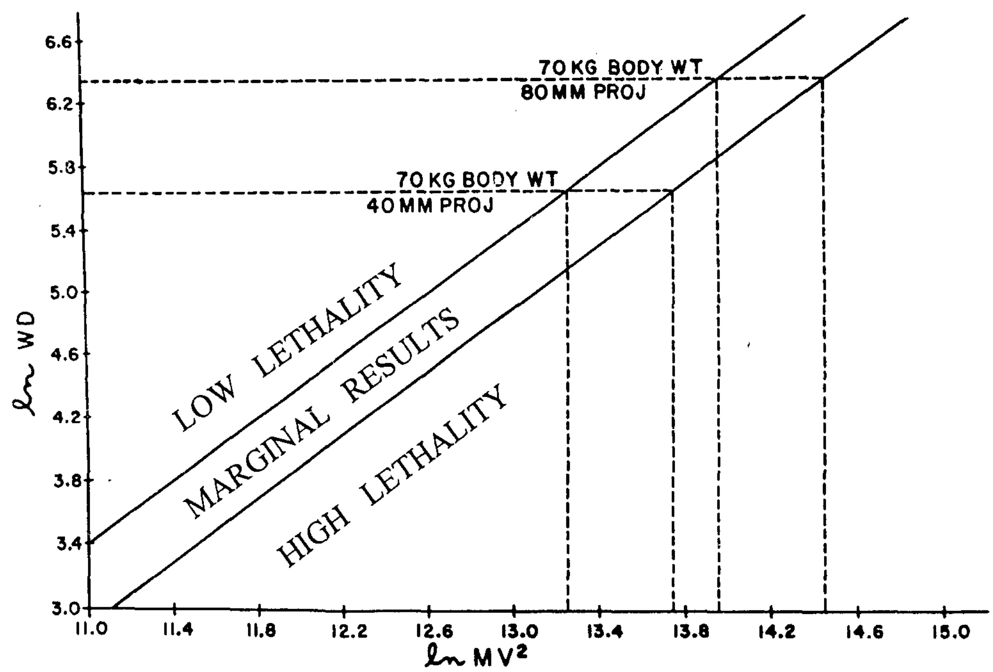

Figure 1. Four parameter generalized model.

In conjunction with the above work, a series of backface signature studies were performed. The ultimate goal was to determine the potential level of injury imparted to the torso of an officer wearing soft body armor. The focus was to develop a simple method to allow police departments to conduct their own evaluation against a known standard. Relying heavily on the animal data collected earlier, the consortium adopted a convenient technique to record a backface signature. This method involves the placement of a body armor sample in front of a 4 inch thick block of calibrated clay. The threat munition is then fired at this arrangement. Provided no perforation of the soft body armor has occurred, the post-shot deformation in the clay is measured. If the cavity depth is 44 mm or greater, the result is considered a failure, with potentially lethal consequences. The detailed procedure is referred to as NIJ standard 0101.03 - Ballistic Resistance of Body Armor.[2]

It has been suggested that this technique be adopted for the evaluation of non lethal munitions by eliminating the body armor and impacting the clay directly.[3] Furthermore, the same 44 mm failure criterion would be utilized. However, the injury mitigating effects offered by the soft body armor and its influence on the backface signature are not fully understood. Therefore, the validity of modifying this procedure, for the purpose of evaluating non lethal munitions, is an area that requires further investigation.

Ballistic Gelatin

Another technique that was investigated for the evaluation of blunt trauma utilizes ballistic, or ordnance, gelatin. In the past, blocks of both 10% and 20% (by weight) gelatin have been used extensively to model penetrating impacts.[4,5] Both temporary and permanent cavities can be observed with this model as well as the depth of penetration and dispersion of fragments. Although some controversy exists over which formulation is more accurate, this material has been used to determine both the rate of energy deposition and the total energy deposited within a target, by a penetrating projectile. Again, the adaptation of an established procedure (penetration) for the determination of a non-similar effect (non-penetration) has yet to be validated. However, if several assumptions are made, a reasonable approach can be attempted. The first is that gelatin offers a similar resistance to deformation as that of living tissue. The second is that the depth of temporary deformation can be related to injury potential for thoracic organs. Even though absolute injury levels have yet to be determined, this method should be suitable for determining relative differences from one impact to another. In other words, various projectile impacts can accurately be ranked from most severe to least severe. With these assumptions, the utilization of high speed imaging equipment can illustrate the degree of temporary deformation as well as revealing other impact phenomena.

As another measure of possible tissue response, the level of damage inflicted upon the gelatin could be interpreted as a measure of tissue damage. If a projectile penetrates the gelatin or lacerates the surface, it can be assumed that a similar result would occur in tissue. This is known to be a conservative estimate, due to the fact that the gelatin surface is significantly less elastic than the epidermal layer (skin). Therefore, if no damage to the impacted surface of the gelatin is observed, it can be assumed that soft tissue would respond in a similar fashion. Of course this method does not account for interactions with underlying bony structures which could influence the potential for laceration.

Vehicular Crash Testing

Over the past several decades, the automotive industry has greatly improved the fidelity of its biomechanical surrogates (crash dummies), developed as tools for injury evaluation in vehicular collisions. More specifically, General Motors Research Laboratories (GMRL) has developed a method of analysis to determine injury level to the thorax.[6] Referred to as the Viscous Criterion (VC) this response has been documented to predict the severity of soft tissue injury and cardio-respiratory dysfunction caused by blunt impact. The technique utilizes measurements taken from a biomechanical surrogate undergoing an impact event. The VC is then calculated from time dependent displacement data provided by a chest transducer. The chest compression (C) is defined as the displacement of the chest in relationship to the

spine, normalized by the initial thickness of the thorax. The time dependent product of the velocity of the chest deformation (V) and the amount of compression (C) form the VC.[7] Thus, this criterion is dependent upon not only the amount of compression, but also the rate at which the compression occurs.

The adaptation of a biomechanical surrogate for use in evaluating non-penetrating ballistic events seemed a logical extension. Collaboration between GMRL and the Institute for Preventative Sports Medicine has led to the development of a portable surrogate with biofidelity regarding human chest response due to non lethal projectile impact. This device is referred to as the three-rib chest structure (3-RCS). The development of the 3-RCS involved the extraction of sub-units from a current generation crash dummy, the BIOSID. The rib structures of the BIOSID were considered ideal for non-penetrating chest impacts because they were continuous in the sternum area, and therefore provided realistic loading surfaces. The basic design of the 3-RCS involves three thorax ribs mounted to a spine box opposite the impact face. Dampening material on the inside of the steel ribs provides for viscous bending resistance and increases the dissipation of energy. Nylon supports, mounted to the sides of the spine box, prevent gross upward or downward motion of the ribs. A urethane bibb ties the three ribs together on the impact side. The urethane is covered with a sheet of Ensolite foam (approximately 5/8 inch thick) to simulate overlying skin and subcutaneous tissue. A conductive-plastic position transducer was mounted to the interior of the rib structure to allow measurement of the center rib displacement relative to the spine box.

As stated previously, the impact phenomena associated with non lethal munitions are low-mass and high-velocity in nature; as opposed to the high-mass, low-velocity impacts indicative of automotive collisions. Although preliminary verification testing has been conducted, a comprehensive system validation, over a broad range of impact conditions, has not been completed. However, this work is scheduled to take place over the next two years.

TEST DATA

Backface Signature in Clay

The data obtained using the modified NIJ backface procedure was the result of tests conducted at the Army Research Laboratory, on several occasions. In addition, data was supplied by Defense Technology Corporation. The target consisted of a 24 inch x 24 inch x 4 inch thick block of clay rigidly confined on all four sides and the rear. The front of the target was situated to present a 0° angle of obliquity, relative to the velocity vector of the projectile. The impact face of the target was exposed clay with no intermediate covering. Pre-test calibration of the clay was conducted according to NIJ standard 0101.03. Velocity screens provided a projectile velocity approximately 1 meter from target impact. For this study the velocity recorded at this location will be referred to as the impact velocity. Table 1 contains the results of testing conducted by Defen.. Technology for a variety of munitions.[8] Both the deformation and impact velocities provided had been averaged over the number of test shots (typically 10 - 20 shots per munition). Table 2 contains ARL test results for one 12 gage munition and two versions of the 40mm Sponge Grenade (XM1006) at various impact velocities. Unlike the previous table, each row here contains data from an individual firing.

PROJECTILE TYPE	MASS (gm)	IMPACT VELOCITY (m/s)	CAVITY DEPTH (mm)	IMPACT ENERGY (J)	ENERGY DENSITY (J/cm^2)
12 gage Single Ball #23SB	3.4	283.1	39.5	136.2	74.7
12 gage Shot Bag #23 BR	40.8	87.9	33.3	157.6	N/A
12 ga Wood Baton #23 WB	3.35	276.5	40.3	128.0	N/A
12 gage Fin Slug #23 FS	5.68	154.9	30.6	68.1	N/A
40mm Multi Pellet (.32 cal) #40A	0.27 each	87.4	3.0	1.0	1.93
40mm Multi Pellet (.60 cal) #40B	2.27 each	100.7	6.8	11.5	6.32

40mm Sand Bag #40BR	104.7	69.2	35.0	250.6	N/A
40mm Wood Baton #40W	23.0 each	79.4	25.0	72.5	6.90
40mm Foam Baton #40F	18.6	79.6	6.5	59.0	5.35

Table 1. Defense Technology test results from modified clay signature testing.

PROJECTILE TYPE	MASS (gm)	IMPACT VELOCITY (m/s)	CAVITY DEPTH (mm)	IMPACT ENERGY (J)	ENERGY DENSITY (J/cm^2)
12 gage Wood Baton #23 WB	3.83	207.3	23.8	82.3	N/A
40mm XM1006	57.8	60.9	31.75	107.2	8.53
40mm XM1006	57.8	60.6	25.4	106.1	8.44
40mm XM1006	30.2	87.2	22.2	114.8	9.14
40mm XM1006	30.2	89.3	28.6	120.4	9.58
40mm XM1006	57.8	53.3	22.2	82.1	6.53
40mm XM1006	57.8	50.3	19.0	73.1	5.82
40mm XM1006	30.2	78.4	22.2	92.8	7.39
40mm XM1006	30.2	75.6	22.2	86.3	6.87

Table 2. ARL test results from modified clay signature testing.

As a first order analysis, the kinetic energy of a given impact has been plotted against cavity depth and included as Figure 2. As anticipated, the data displays a roughly linear trend between kinetic energy and cavity depth. Only one projectile type, the 40 mm sand bag, deviated considerably from this trend. Although not thoroughly understood, it is conjectured that the conforming nature of this device contributes significantly to its ability to dissipate higher energy levels, without producing a deeper cavity. However, this simple energy approach ignores many factors; such as the area over which energy is deposited, the projectile shape, and the materials used in its construction. It should be noted that a number of these projectiles are fabricated using compliant materials, which will deform upon impact, while others utilize non-compliant materials. The exact influence that these factors have on cavity formation is largely unknown.

A more appropriate approach may be to plot the cavity depth as a function of energy density. This would include an impact area term. However, such an area is difficult to assume for certain munitions, such as unstable projectiles, which tumble during flight, as well as shot bags. Therefore, Figure 3 includes a plot of cavity depth versus energy density, expressed as J/cm^2, for those devices that allowed a reasonable determination of impact area. An interesting result is obtained from this analysis. Each munition possesses an energy density of less that 10 J/cm^2, except for the 12 gage single ball which delivers almost 75 J/cm^2, displacing itself to the far right side of the plot. It was observed that this rubber sphere impacted with a velocity large enough to produce an oversized crater, thereby dissipating a significant fraction of energy in the radial direction. Whereas the other projectiles contained within this plot impacted with a much lower velocity, producing craters slightly larger than themselves.

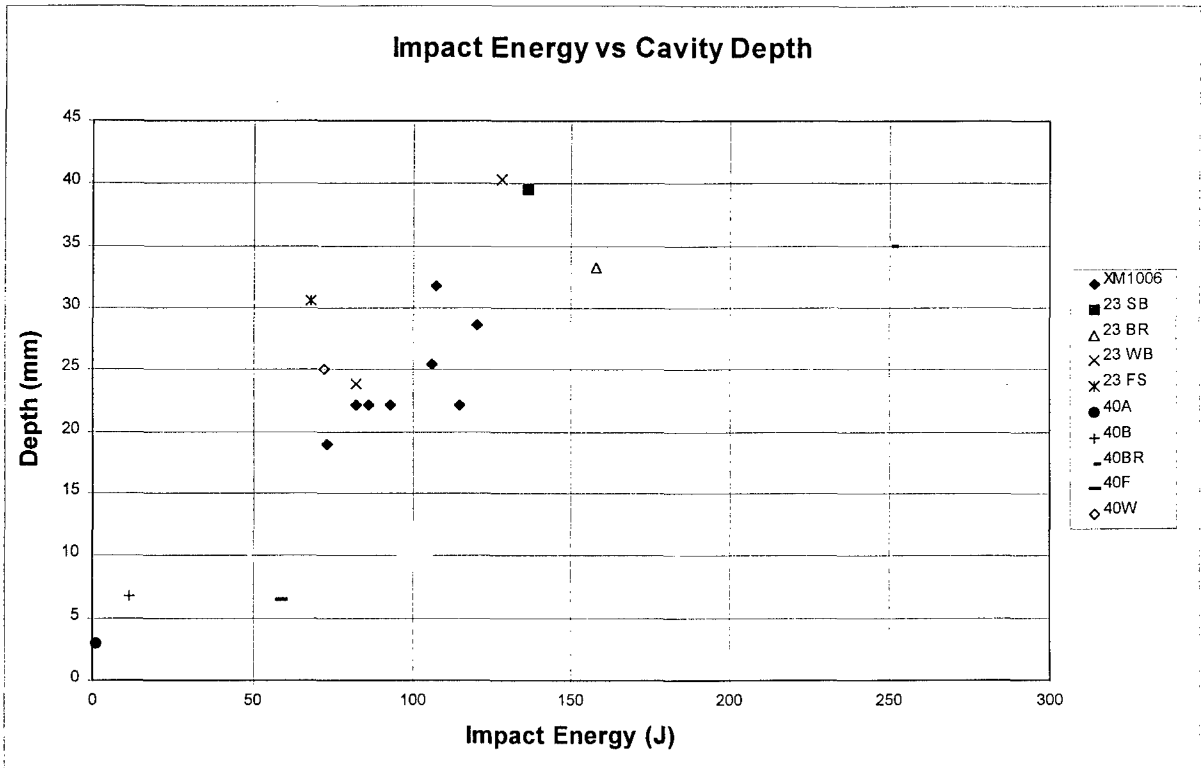

Figure 2. Results from clay signature testing plotted as a function of kinetic energy.

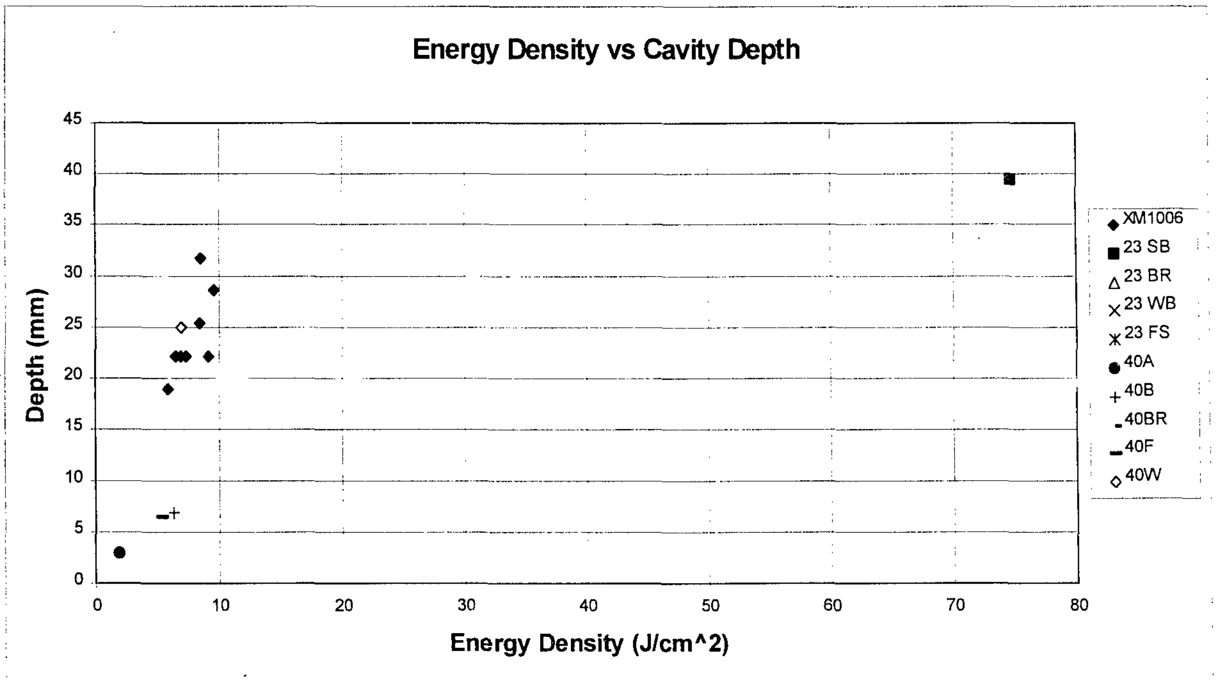

Figure 3. Results from clay signature testing plotted as a function of energy density.

Ballistic Gelatin

A series of firing tests were conducted for this study which utilized blocks of 10% (by weight) ballistic gelatin (type 250A Ordnance Gelatin). This formulation has been shown to provide a close simulant to the disruption experienced in living tissue, such as muscle, when subjected to projectile penetration.[9] The gelatin powder was reconstituted using 180° F (82.2 C) water, surface bubbles skimmed, then poured into

molds and chilled to 40° F (4.4 C). Approximately 24 hours later the blocks were removed from the molds, wrapped in air-tight plastic bags, and again stored at 40° F (4.4 C) for an additional 24 hours. The face of each block measured roughly 5 inch x 5 inch with a length of 15 inches. In preparation, the impact surface was covered with a single layer of T-shirt material (100% cotton, 48 threads per inch). All testing was conducted within 30 minutes of removal from the refrigerator to minimize temperature effects. Several blocks were calibrated using an air rifle, firing a 0.177 inch BB at 590 ft/s +/- 15 ft/s (179.8 m/s +/- 4.5 m/s). The calibration specification states an ideal static penetration of 8.5 cm +/- 1.0 cm.[10] All calibration shots resulted in penetration numbers within these limits. Impact events were recorded using a high speed video system, set to record at a frame rate of 9,000 frames per second. In order to provide a reference distance with which to measure temporary deformation, a transparent ruler was attached to the side of each test block. By framing through the recorded video image, a maximum deformation could be measured. The following table (Table 3), contains the results of testing conducted by ARL on several occasions with various munitions.

PROJECTILE TYPE	MASS (gm)	IMPACT VELOCITY (m/s)	TEMPORARY CAVITY (mm)	IMPACT ENERGY (J)	ENERGY DENSITY (J/cm^2)
40mm XM1006	28.53	88.7	63.5	112.2	8.93
40mm XM1006	28.80	91.1	61.9	119.5	9.51
40mm XM1006	29.30	91.7	63.5	123.2	9.80
40mm XM1006	29.17	75.9	60.3	84.0	6.68
40mm XM1006	28.85	56.7	47.6	46.4	3.69
40mm XM1006	28.43	59.1	52.4	49.7	3.96
40mm XM1006	27.32	100.0	63.5	136.6	10.87
12 gage Single Ball #23 SB	3.40	306.8	95.25 (73.1) P	160.0	87.7
12 gage Shot Bag #23 BR	39.79	108.4	158.8 (133.3)P	233.8	N/A
12 gage Shot Bag #23 BR	40.46	92.5	146.1 (101.6)P	173.1	N/A
12 gage Shot Bag #23 BR	39.87	91.9	130.2 (79.4)P	168.4	N/A
12 gage Multi Pellet #23RP	0.41 each	110.9	15.9	2.5	4.82
12 gage Fin Slug #23 FS	5.59	159.3	50.8 (26.7)P	71.2	N/A
12 gage Fin Slug #23 FS	5.61	166.6	57.2 (25.4)P	77.9	N/A
12 gage Fin Slug #23 FS	5.60	127.9	47.6	45.8	N/A
40mm Multi Pellet (.32 cal) #40A	0.41 each	61.4	12.7	0.77	1.48
40mm Multi Pellet #40A	0.41 each	73.8	9.5	1.1	2.12
40mm Multi Pellet #40A	0.41 each	78.8	19.1	1.3	2.51
40mm Multi Pellet #40A	0.41 each	83.1	12.7	1.4	2.70
40mm Multi Pellet (.60 cal) #40B	2.20 each	93.4	47.6	9.6	5.26
40mm Multi Pellet #40B	2.20 each	92.8	41.3	9.5	5.21
40mm Multi Pellet #40B	2.20 each	88.5	41.3	8.6	4.71
40mm Multi Pellet #40B	2.20 each	86.7	28.6	8.3	4.55
40mm Multi Pellet #40B	2.20 each	109.1	27.0	13.1	7.18
40mm Foam Baton #40F (3 each)	14.0 each	105.2	63.5	77.6	7.04
40mm Foam Baton #40F	14.0 each	103.0	50.8	74.3	6.74
40mm Foam Baton #40F	14.0 each	101.9	63.5	72.7	6.59

40mm Foam Baton #40F	14.0 each	102.6	60.33	73.7	6.68
40mm Wood Baton #40W (3 each)	20.0 each	78.2	95.3 (19.0)^P	61.2	6.16
40mm Wood Baton #40W	20.0 each	77.1	114.3 (31.2)^P	59.4	5.98
40mm Wood Baton #40W	20.0 each	81.8	101.6	66.9	6.74

Table 3. Results from ballistic gelatin testing.

Several of these impacts resulted in penetration of the gelatin, in addition to temporary deformation. These instances are noted by an additional entry in the temporary deformation column, denoted using ( )^P. This number refers to the static penetration of the block, relative to the impact surface. A data analysis similar to that applied with the clay data was employed. Figure 4 contains the deformation as a function of impact energy while Figure 5 plots the energy density as a function of deformation.

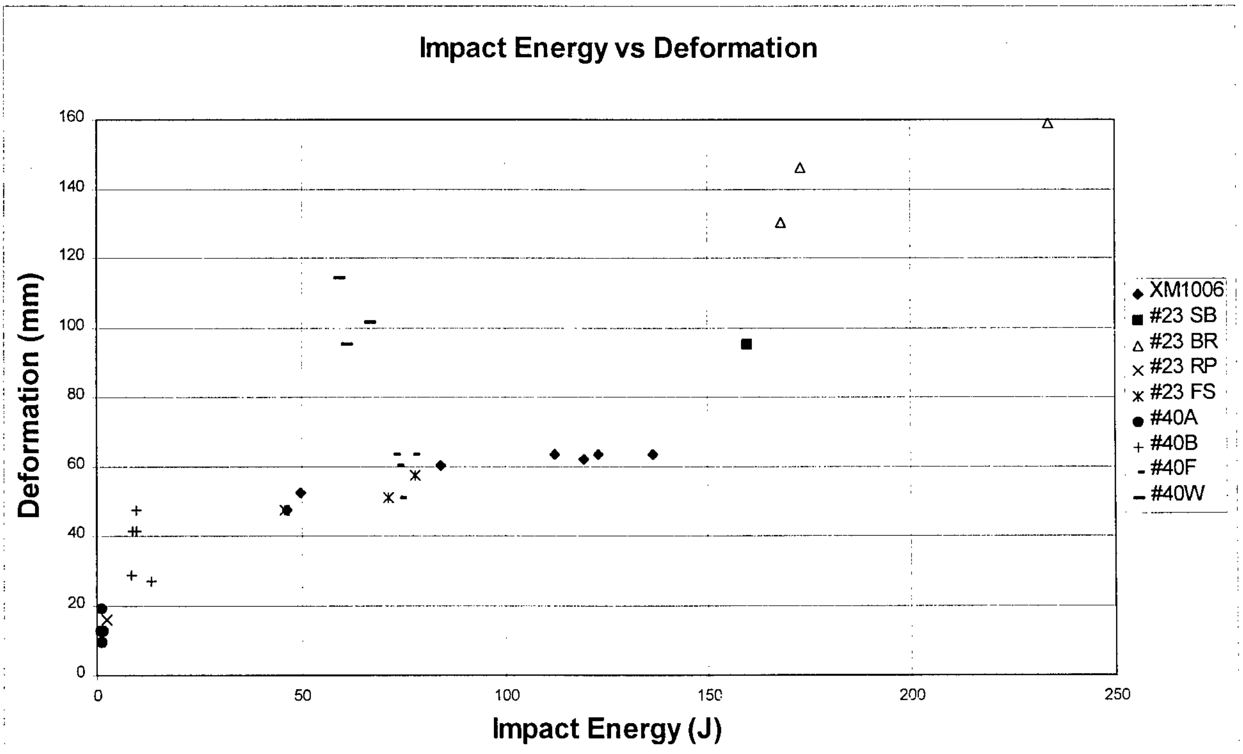

Figure 4. Results from gelatin testing plotted as a function of kinetic energy.

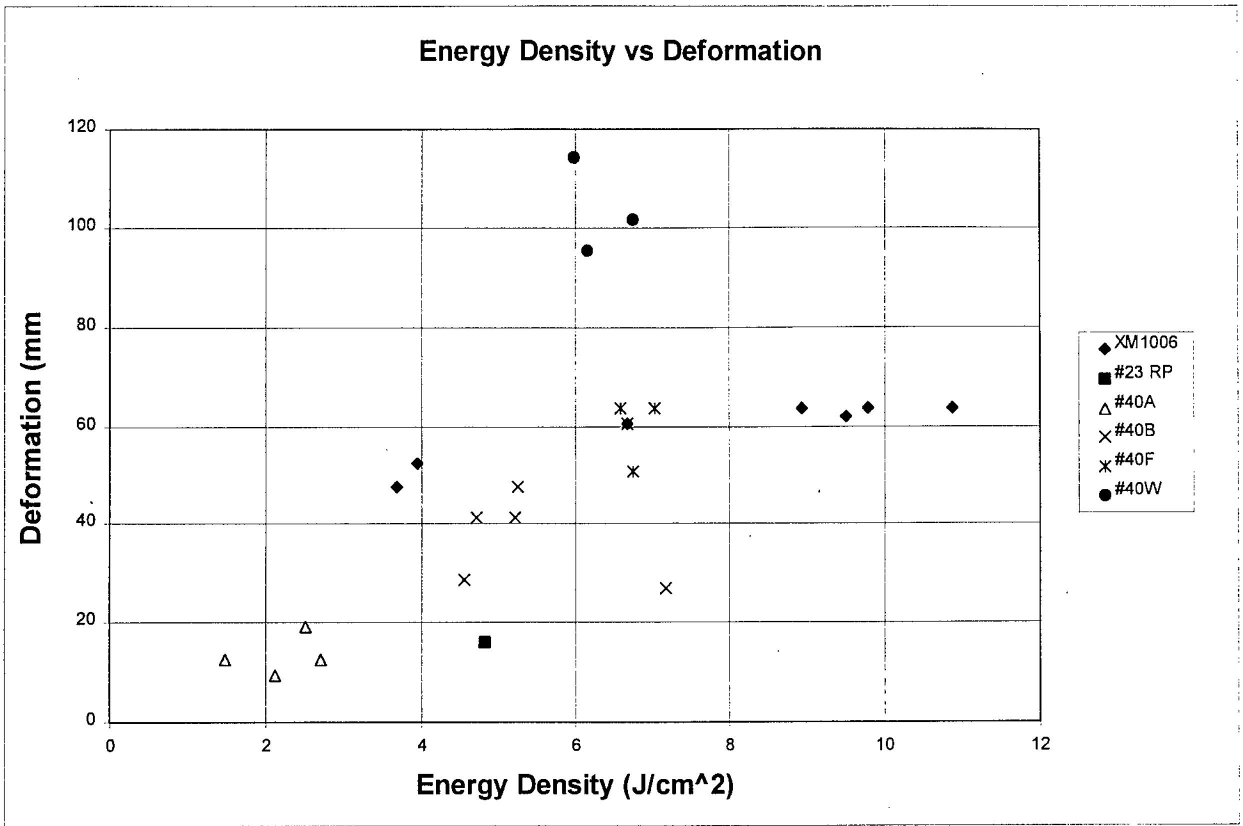

Figure 5. Results from gelatin testing plotted as a function of energy density.

3-Rib Chest Structure

Experimental evaluations have also been conducted with the 3-RCS on a variety of non-lethal munitions. As the testing procedures have evolved, the analysis of the measurement data has been refined. Based on testing conducted in the fall of 1997, where high speed video was utilized, several limitations were placed on the resulting data from the 3-RCS. Specifically, due to the high rib velocities which these impacts induce, the transducer must be capable of tracking higher velocity rib displacements than those seen in automotive impacts. From observing the video and comparing it to the measured displacement, it was noted that the maximum transducer displacement did not always correspond with the video. This was especially true with the higher kinetic energy impacts, which produced much higher rib velocities. This energy transfer rate creates a large spike of noise in the output. By applying the proper filter, the majority of this phenomenon is eliminated, without clipping real displacement data. Therefore, a maximum velocity constraint of $\leq$10m/s was established for the measurement data. This also corresponded to specifications of the transducer.

Impact location was also considered a critical parameter. Currently, the transducer only records the amount of chest displacement experienced by the middle rib. By virtue of this design, if one of the other ribs experiences the majority of the energy transfer, the transducer is unable to track an accurate amount of chest displacement. This is best seen on the high speed video where an impact to the upper or lower rib causes large displacements in the respective rib and minimal displacement in the middle rib. The establishment of a region of acceptable impact locations overcomes this problem.

Given these limitations, data were analyzed for a variety of munitions. Only those impacts where impact was made in the center region and the displacement measurement was less than 10 m/s are presented.

PROJECTILE TYPE	MASS (gm)	IMPACT VELOCITY (m/s)	CHEST DISPLACEMENT (mm)	IMPACT ENERGY (J)	VC
40mm XM1006	28.83	71.0	7.22	72.7	0.08
40mm XM1006	29.30	70.0	7.12	71.8	0.08
40mm XM1006	57.68	52.0	8.21	78.0	0.19
40mm XM1006	29.17	76.0	6.44	84.2	0.08
40mm XM1006	28.50	77.0	6.68	84.5	0.12
40mm XM1006	28.88	77.0	7.66	85.6	0.14
40mm XM1006	58.09	55.0	8.78	87.9	0.16
40mm XM1006	28.61	80.0	5.90	91.6	0.09
40mm XM1006	57.18	57.0	7.41	92.9	0.19
40mm XM1006	56.91	58.0	8.00	95.7	0.16
40mm XM1006	57.95	60.0	9.64	104.2	0.19
40mm XM1006	28.00	87.0	9.00	106.0	0.14
40mm XM1006	28.99	88.0	9.36	112.2	0.20
12 gage Single Ball #23 SB	3.70	346.0	5.00	221.4	0.09
12 gage Single Ball #23 SB	3.70	326.0	7.58	196.6	0.02
12 gage Shot Bag #23 BR	41.0	94.0	10.90	181.1	0.28
12 gage Shot Bag #23 BR	41.0	92.0	9.50	173.5	0.24
12 gage Shot Bag #23 BR	41.0	98.0	12.06	196.9	0.19
40mm Sand Bag #40 BR	100.0	66.0	12.70	217.8	0.20

Table 4. Results from 3-RCS testing.

Figure 6 contains a plot of VC versus impact energy. This plot does reveal a positive correlation for the XM1006 data (R=.494). However, there are too few data points from any other munition to allow a similar analysis.

SUMMARY and CONCLUSIONS

Three experimental evaluation techniques have been described and exercised using a variety of non lethal munitions. Results from the first two (clay backface signature and ballistic gelatin) have been presented in the form of raw data, followed by a basic data analysis which included plotting as functions of both energy and energy density. This approach showed linear trends with one munition falling far outside the established bounds. The third technique (3-RCS) assigned a VC to each impact which corresponds to a level of injury. This device resulted in a correlation between kinetic energy and VC for the for Sponge Grenade (XM1006) data.

It should be noted that none of the available techniques have been fully validated for the assessment of non-penetrating, blunt impacts. Therefore, a more extensive analysis of both the methodology and data are warranted. However, this study represents the first attempt to compare results obtained from different experimental techniques, in an effort to evaluate injury levels. The estimate of injury, even for a single region of the body, is an extremely complex undertaking. It is not clear that any of the techniques included here are able to fully predict actual injury level. Be that as it may, the results provide a comparative ranking of injury severity, relative to one another.

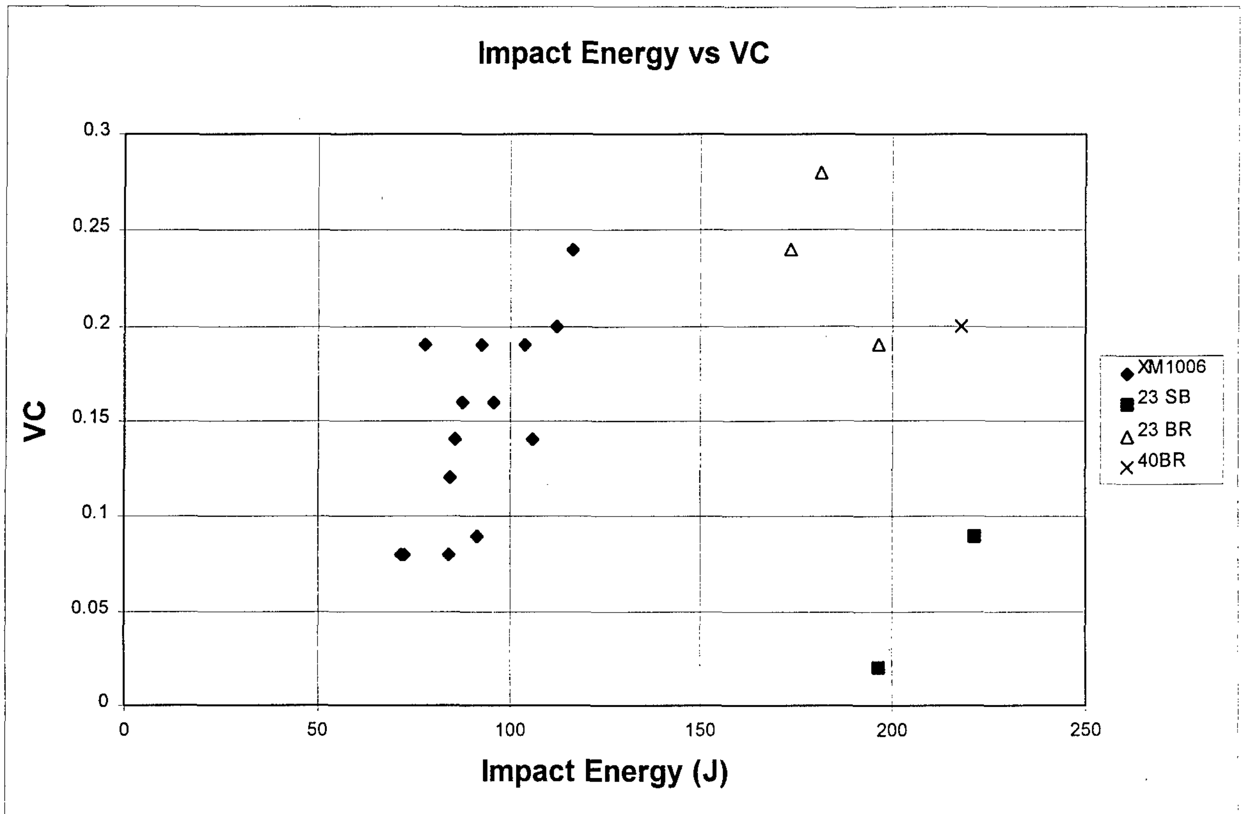

Figure 6. Impact energy versus Viscous Criterion (VC).

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HEALTH RISK ANALYSIS OF FIRST DEFENSE® PEPPER SPRAY USING AN ACUTE WHOLE-BODY INHALATION EXPOSURE

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ABSTRACT

The use of chemical agents on individuals has been practiced throughout this century in various arenas. The use of tear gas by the military in foreign conflicts first proved the effectiveness of this method to deal with combatants. Throughout this period, domestic law enforcement agencies faced the challenge of dealing with civil disturbances in the U.S. With the increased use of chemical agents by both the law enforcement community and the military, the need to find a safer and more effective product has been explored. The introduction of oleoresin capsicum, a natural extract of chili peppers, has been embraced as a more effective means to deal with individuals with a high tolerance for pain or individuals under the influence of drugs or alcohol. However, the rush to find a safer and more reliable replacement to the traditional defense sprays, CS and CN, has led to a flood of pepper sprays on the market. This haste has allowed products to become available that may be even more harmful than what they were intended to replace. The purpose of these studies was to evaluate any short term toxicity associated with a one-minute whole body inhalation exposure of First Defense Pepper Spray. More specifically, the intent was to determine if a level of lethality existed under this exaggerated laboratory setting. Based on the range finding and limit tests, the one-minute acute inhalation LC50 of First Defense was estimated to be greater than 5.76 mg/L in the rat and 5.80 mg/l in the mice. In addition, no mortalities occurred during either study.

INTRODUCTION

The ability to enhance officer safety while minimizing the risk of injury to a suspect has long been a goal within the law enforcement and correctional communities. In order for a tool to be effective, it must have the ability to deter individuals from an unwanted action or provide a means to aid in incapacitation or apprehension. Pepper spray accomplishes this task by eliciting an undesirable response when the active ingredient, oleoresin capsicum, comes in contact with the eyes, nose, and mucous membranes. This response is in the form of a burning sensation upon contact, causing inflammation and tearing of the eyes, which leads to involuntary closure. Should the spray become inhaled, it can cause swelling to the mucous membranes and a sensation of shortness of breath. This effect, combined with involuntary closure of the eyes, is a very useful tool within the force continuum.

Previous studies have been conducted on First Defense to determine the aerodynamic particle size of the spray when actuated. The findings have been incorporated and are useful when quantifying exposure levels. As a further method to ensure the safety of First Defense, a whole-body inhalation exposure was performed on two species of rodents. This route of exposure was chosen, as it would most likely mimic the application of the spray to humans. An initial study was conducted on Sprague-Dawley rats in order to determine any short-term toxicity of the product and to provide valuable information in assessing the health risk of First Defense. A follow-on study was conducted on CD-1 mice in an attempt to duplicate the findings in an alternate species and further validate the data and methods.

BACKGROUND

The use of chemical agents on individuals has been practiced throughout this century in various arenas. The use of tear gas by the military in foreign conflicts first proved the effectiveness of this method to deal with combatants. Throughout this period, law enforcement agencies faced the challenge of dealing with civil disturbances in the U.S. The lack of manpower and tools to adequately deal with these types of conflicts, without resorting to the use of lethal force, prompted the need for an alternative method. Incorporating the use of tear gas and the tactics used by the military to dispense the agent, effectively controlling large crowds and aggressive or threatening individuals, provided the much-needed solution for law enforcement.

Throughout the use of chemical agents, the need to find a safer and more effective product has been explored. The introduction of oleoresin capsicum, a natural extract of chili peppers, has been embraced as a more effective means to deal with individuals with a high tolerance for pain or individuals under the influence of drugs or alcohol. The placement of pepper spray within the force continuum deleted the void between verbal commands and soft contact, where resistance is not anticipated, and the use of blunt force (fist or baton). The implications of this addition are several fold. First and foremost, the ability of an officer to remove themselves from a situation in which blunt force is involved benefits both the officer and the suspect. Statistics from the Missouri Highway Patrol show that the weapon of choice 8 out of 10 times with suspects is the hands and feet (Dec. 91). Without an alternative method or tool, the officer is forced to use at least the level of force dictated by the suspect, if not more. However, by using pepper spray, the officer or soldier can preclude the need for violence or blunt force and effectively "take the fight out of the fighter". By reducing the level of force needed to resolve an issue, the risk of injury to both parties is greatly reduced. A benefit often overlooked, is the use of these products as a visual deterrent when used with verbal commands. The ability to draw the pepper spray and threaten the use of it, may often be sufficient to resolve an issue without the use of force.

Even though pepper sprays were used as early as 1977 in the United States, it wasn't until about 1992 that they gained widespread use. The use of pepper sprays to incapacitate individuals, either from a defensive standpoint or as a deterrent from unwanted action, has become a useful tool to law enforcement. However, the rush to find a safer and more reliable replacement to the traditional defense sprays, CS and CN, has led to a flood of pepper sprays on the market. This haste has allowed products to become available that may be even more harmful than what they were intended to replace. With no regulatory agency overseeing and setting guidelines in the production of these sprays, the responsibility of providing a safe product to the consumer rests solely with the manufacturer.

STUDY DESIGN

Sprague-Dawley Rats

This study was designed to assess the short-term toxicity of First Defense in Sprague-Dawley rats when administered by a one-minute, whole-body inhalation exposure. The study was designed to

provide information under exaggerated clinical use conditions and is a follow-on study to an earlier aerodynamic particle size analysis.

The study facility was provided with the test article from lot number OC557. An independent analysis verified the contents ingredients as follows; capsaicinoids 0.21%, ethanol 28%, propylene glycol 13%, and water 59% (3). The study consisted of two parts, a range-finding test and a limit test.

Range-Finding Test

The study was initiated with a range-finding test using one male and one female rat at three different exposure levels. The test article was generated into an aerosol with TSI Model 9306 6-Jet Atomizers. The aerosol was blown through a RHS-100L whole-body inhalation chamber and then vented from the chamber and collected with an air treatment system, which consisted of a pre-filter, HEPA filter, a charcoal bed, and a water scrubbing tower. Once the aerosol was generated inside the chamber, the lid was carefully removed and the appropriate animals were gently placed inside. The lid was then carefully placed back on the chamber for the duration of the exposure. Care was taken to minimize the disruption of the test article aerosol.

Each aerosol exposure lasted for a period of one minute. The chamber pressure was measured prior to the initiation of each exposure and was maintained at a slightly positive pressure. The aerosol concentration was measured by gravimetric techniques in the breathing zone of the chamber just prior to the introduction of the animals. After each exposure, the animals were removed from the chamber and any residual test article was rinsed from the hair coat. The animals were dried with a towel and returned to their cages. The animals were observed twice daily for seven days, until completion of the study.

Limit Test

Upon completion of the range-finding test, a limit test was conducted on five male and five female Sprague-Dawley rats. The test article was generated into an aerosol and delivered to the chamber in the same manner as in the range-finding test. The chamber air flow was maintained slightly positive and the aerosol concentration was recorded once prior to initiation and once during the exposure. In addition, chamber temperature and humidity were recorded prior to the study. An aerosol aerodynamic particle size distribution was conducted prior to the exposure using an ITP 7 L/min. cascade impactor.

The animals were placed into the chamber in the same manner as with the range-finding test. After a one minute exposure, the animals were removed and test article residue was rinsed off and the animals towel dried. The animals were placed back into their cages and observed twice daily for 15 days. At the completion of the study, day 15, the animals were euthanized by carbon dioxide inhalation and a gross necropsy was performed.

CD-1 Mice

A follow-on study was conducted on CD-1 mice in order to validate the study design and protocol.

Range Finding

A range finding test was not conducted on the CD-1 mice. The levels obtained in the previous species will be used to determine the limit test.

Limit Test

The limit test was conducted on the CD-1 mice in the same manner as carried out with the Sprague-Dawley rats. The one exception was that the animals were euthanized with necropsy on day 14.

RESULTS

Sprague-Dawley Rats

The three exposure levels tested in the range finding were 2.56 mg/L, 5.04 mg/L, and 8.42 mg/L. No mortalities were produced at any of these levels. Based on these findings, the concentration selected for the limit test was 8.50 mg/L prior to the introduction of the animals. Once the lid was placed back on the chamber, the test article concentration was measured at 5.76 mg/L during the exposure. The aerodynamic particle size of the test article generated in the chamber was $3.5\mu \pm 1.7\mu$ (microns). The chamber temperature and relative humidity was 76.8°F and 63.2%, respectively. The oxygen content within the chamber was maintained at 21% throughout the study.

An attempt was made to observe the animals during the aerosol exposure period. However, due to the density of the test article, the animals could not be seen. The most notable clinical signs once the animals were removed from the chamber included salivation, lacrimation, urine stain, and dark material around the facial area. No mortalities occurred during the limit test and all animals survived to the completion of the study. On day 15, the animals were euthanized and a gross necropsy was performed. No significant internal findings were observed.

CD-1 Mice

The aerosol concentration for the limit test was 8.62 mg/l (pre-exposure) and 5.80 mg/l (during exposure). The aerodynamic particle size of the test article generated in the chamber was $3.3\mu \pm 1.8\mu$. The chamber temperature and relative humidity was 66.9°F and 70.4%, respectively. The oxygen content within the chamber was maintained at 21% throughout the study.

No mortality occurred during the study. The only notable clinical observations were ocular discharge in four animals on day 0, and a slight body weight loss in two female mice between day

7 and 14. All other animals experienced body weight gain or maintenance during the study. There were no gross internal findings observed at necropsy on study day 14.

DISCUSSION

The purpose of these studies was to evaluate any short term toxicity associated with a one-minute whole body inhalation exposure. More specifically, the intent was to determine if a level of lethality existed under this exaggerated laboratory setting. Based on the range finding and limit tests, the one-minute acute inhalation LC50 of First Defense was estimated to be greater than 5.76 mg/L in the rat and 5.80 mg/l in the mice. Using this information and data collected from an earlier particle size analysis (4), conclusions can be drawn as to the health risk of using First Defense.

Particle size is generally considered the critical factor that determines the region of deposition within the respiratory tract (5). It has been previously determined that 1,182 grams of test article discharged into a 22 liter collection chamber produced an aerosol concentration of 0.057 mg/L (4). Of the percent aerosolized, 0.0001%, the mass median aerodynamic particle size and geometric standard deviation was calculated to be $6.0\mu \pm 4.2\mu$. The aerosol was generated by impacting the stream onto a flat surface within the chamber from a distance of 18 inches. The resulting aerosol was drawn through an air treatment system similar to the one used in the limit test.

The information gathered in these studies provides a useful mechanism in evaluating the health risk of First Defense. In addition to these findings, there are other guidelines in place to ensure the safety of this product. The approach to safety is multi-faceted, encompassing engineering and quality controls. The ability to contain the formulation in a stream prevents smaller particles from being generated, which are more readily respirable. Quality control regulates that the amount of active ingredient present in the formulation to be within the range of 0.18 - 0.22 percent. This is verified by an independent laboratory analysis on each lot prior to filling.

Beyond these controls, several conditions exist in these studies that would be extremely difficult to produce in an actual field use of First Defense.

- The aerosol generated in the particle size analysis was impacted from a minimal distance of 18 inches onto a flat surface. This close range and flat surface produces an elevated aerosolization rate compared to what would be generated from an impact greater than the recommended three feet. Furthermore, the contour of the human face would likely deflect much of the spray, quite possibly away from the nasal and oral cavities. Even if little is deflected, the aerosol generated would then have to be respired shortly after impaction so as not to be affected by environmental conditions, such as a breeze.

- The possibility of generating an aerosol concentration of 5.76 mg/L in an outdoor application is almost unachieveable. Situations could occur where an individual may be sprayed in an enclosed environment, such as a car or prison cell. However, the amount needed to generate that concentration is highly unlikely with hand held units. For

reference, based on the particle size analysis of First Defense, 14 MK4 units, or 1,182 grams, were discharged into a collection chamber producing an aerosol concentration of 0.057 mg/L. The chamber was approximately the size of a 5 gallon bucket, and yet still only produced a level roughly 1/100 of the level tested in the rat and the mice.

- Lastly, the ability to sustain this concentration for a one-minute continuous exposure would be difficult to produce. It is noted that individuals in physical exertion or duress will have an increased respiratory demand. However, even with increased respiration, the amount that could be respired would be far below the amount generated in a one minute exposure.

CONCLUSION

Based on the information provided in these studies and the conditions associated with its use, the potential acute health risk of using First Defense from an inhalation exposure, would appear to be extremely minimal. However, it should be noted that individuals with respiratory conditions such as emphysema, asthma, or bronchitis may be more sensitive to any foreign agent.

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Extended Range Less Lethal Stand-Off Capabilities: A 66mm Stingball Grenade

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ABSTRACT

A deficiency has been identified in the ability for U.S. soldiers, in the role of peacekeepers, to keep unarmed combatants at a safe stand-off distance. While these individuals may be unarmed, the threat that they pose steadily increases as their distance decreases. The ability to maintain a "safe-zone" or stand-off distance in a less lethal manner is the intended outcome. In order to accomplish this task, a method to move and or rout these individuals, while promoting area denial, is needed. This paper presents a less lethal, extended range stand-off using existing materials and weapon platforms. Materials were obtained from the L8 Smoke Grenade and used to test a 66mm Stingball and or an Aerial Distraction Device. This 66mm stingball consists of a five and a half inch rubber body that contains rubber balls and an explosive charge tube. Upon detonation, the rubber body splits and the rubber balls are dispersed in roughly a 360° pattern. The sound report of this explosion is sufficient to be classified as a distraction device. This combined effect is a useful tool in dispersing crowds in a less lethal manner while providing the stand-off needed to ensure the safety of the soldiers, and in doings so, the safety of the combatants as well.

INTRODUCTION

The need for an extended range less lethal standoff capability has prompted research into the design of a 66mm Stingball Grenade. Defense Technology Corporation was awarded funding in the amount of $52,400.00 through the Battelle Scientific Services Program, Task Number 97-138. The purpose was to determine the feasibility of developing a less lethal stand-off munition utilizing the existing 66mm launch platforms. Secondary efforts focused on testing the concept and design, and preliminary performance reviews. Follow-on evaluations will center on performance criteria and safety evaluations.

BACKGROUND

As the U.S. Military emerges as a global police force freeing individuals from civil unrest, offering famine relief, and keeping warring factions apart, the need for less lethal technology becomes more apparent. Not to be overlooked in this area is the need to keep combatants at a safe stand-off distance, as generally the closer a combatant becomes, the greater the threat they pose. The ability to deal with unarmed combatants at an extended range, greater than 30 meters, in a less lethal manner has become a top priority to the U.S. Military.

As unarmed combatants congregate, the level of threat they pose to "peace-keepers" steadily rises. The ability to disperse crowds in a less lethal manner as they gather or loiter has become a problem for U.S. forces and became apparent in Haiti, Somalia, and more recently Bosnia. Less lethal technology is currently available to deal with these combatants in close proximity, i.e. 3 to 30 meters. This technology includes oleoresin capsicum riot agent (pepper spray), specialty impact munitions (foam and wood batons, bean bags, and rubber pellets), noise or diversionary

devices, and rubber pellet grenades. However, because of the inability to maintain a "safe zone", the ability to defuse a potential scenario in which the only alternative becomes lethal force, has not been readily available.

A less lethal stingball grenade that will provide stand-off capabilities out to 100 meters or more in a 66mm configuration would have multiple benefits. First and foremost, this system is compatible with existing United States and United Kingdom 66 mm grenade launchers. The benefits of this system is that these launchers are currently mounted on almost every track and a majority of the wheeled vehicles utilized by the U.S. Army. However, the only available munition has been a CS riot agent or smoke grenade. Concerns have also been raised about the use of chemical agent for crowd control in light of chemical treaty bans.

A 66 mm stingball grenade and or sound diversionary device will fill this extended range void, while not requiring any new equipment or weapon platforms. The benefit is not just in the savings in acquisition of new equipment and launch platforms, but also in soldier training, materials maintenance, and munitions deployment. Because the munitions deploy similar to the current 66mm munitions, there is no increased cognitive skills required for the soldier.

OBJECTIVE

The primary purpose of this effort was to determine the feasibility of producing an extended range less lethal munition. The intent was to develop a munition that would not require any new weapon platform or modification of existing equipment. The effort would focus on the 66mm launch systems, the LVOSS and L8 smoke launcher. In addition, the munition would be designed without the deployment of chemical agent as the primary method to disperse the crowd.

Once the above requirements were met, the concept and design was tested. Upon completion, the munition will be subjected to performance reviews and safety evaluations.

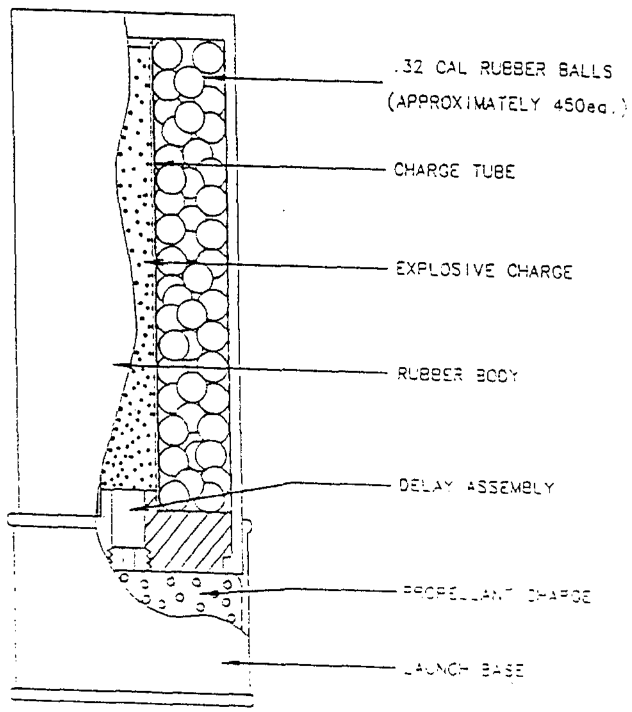
STUDY DESIGN

Concept and Design Phase

The materials that are currently used in the L8 smoke grenade were obtained. The components were examined and the engineering design and feasibility was evaluated. Explosive component combinations were researched. Two standard configurations were chosen; black powder and a flash composition (magnesium, aluminum powder, and potassium perchlorate). The black powder was tested in a 15 gram charge and was chosen based on its relatively stable handling condition. The flash mixture was tested in four charge volumes; 8, 10, 12, and 15 grams.

Static tests were conducted with the explosive charges to demonstrate the feasibility. The munitions were placed in a launch vice and secured. Once fixed in place, the munitions were ignited using standard quick match. The tests were recorded with a standard Hi 8mm video camera placed behind an impact shield at twenty feet. The explosive testing sequence began with black powder and culminated with the 15 gram flash composition. After completion of the static

tests, the munitions were launched without an explosive charge, using a M257 4-tube launcher to determine the launch distances. The launcher was mounted to a metal table stand approximately 30 inches high. The launch tubes were fixed at 20 degrees. The launcher was connected to a 12 volt power supply and wired with a launch switch. The standard L8 smoke launch base and delay was used. Upon completion of the inert launches, the munitions were loaded with the explosive charges and launched as described above.



Two projectile payloads were selected for dispersion testing. Seventy-five durometer "A" scale rubber balls in 0.32 caliber and 0.60 caliber were added to the rubber body of the munitions. Approximately 450 of the 0.32 caliber balls fit into the rubber body, compared to about 50 for the 0.60 caliber balls. The munitions were secured and ignited with quick match. All munitions were static fired using the above charge configurations and test sequence. The 0.32 caliber balls were tested first, followed by the 0.60 caliber balls.

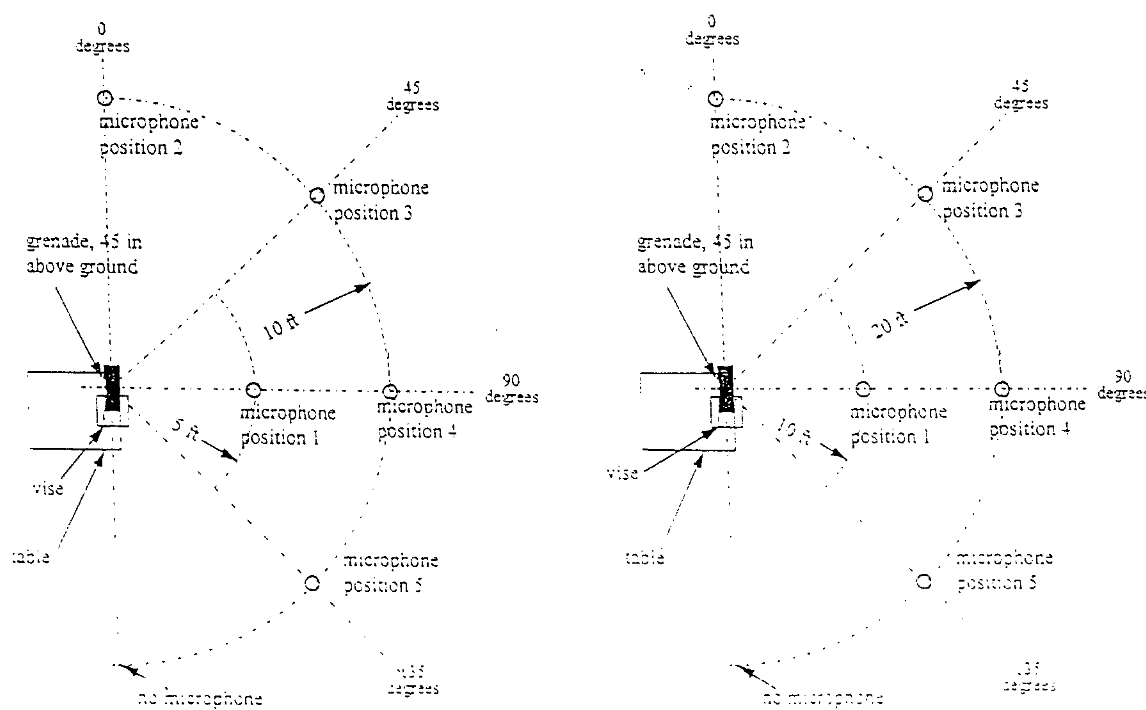
Launch tests were conducted with both calibers of rubber balls with no explosive charge, to determine the achievable launch distance with the increased payload weight. Upon completion of the inert launches, munitions with the explosive charge configurations were launched. The munitions were deployed in the same manner as stated above. The test firings were recorded with the Hi 8mm video camera.

Performance Review

An attempt was made to record projectile velocities using a modified static ignition stand. The munitions were placed within a deflection housing located 36 inches from an Oehler Model 35P chronograph. All charge and projectile variations were tested. A demonstration was conducted at Defense Technology Corporation in Casper, Wyoming, in order to carry out performance testing and to conduct a mid-point review. Static and launch firings were done for each charge configuration and projectile size. High speed and standard video recordings were taken of the static and launch scenarios. Grids were constructed against a rigid wall behind the static launch vice in an attempt to determine projectile velocities using high speed video. Linear distances were recorded for each munition launch from the point of detonation.

Information was obtained from previous impact research studies in which 0.32 caliber and 0.60 caliber balls were tested. Correlations and comparisons were made, where possible, to this blunt injury data which includes modeling clay, gelatin, and a biomechanical surrogate; 3-Rib Chest Structure. A review of other safety and performance data was conducted on similar products that have been tested.

Noise level testing was conducted in accordance with the general requirements of MIL-STD-1474. Five B&K type 2231 sound level meters with type 4136 1/4 inch microphones were arranged in a semi-circular arc, as shown in the below figure. Tests were conducted at five and ten feet, and ten and twenty feet.

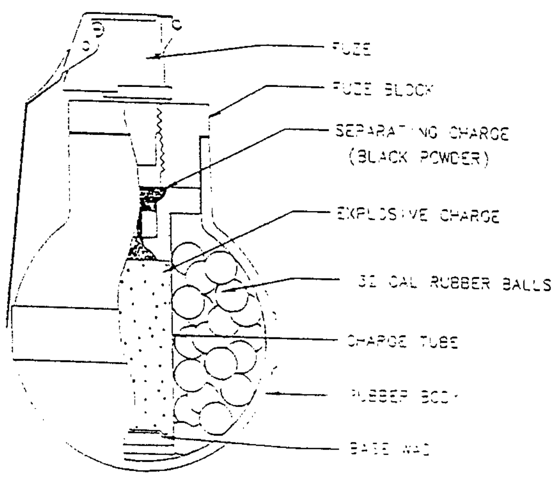


RESULTS/DISCUSSION

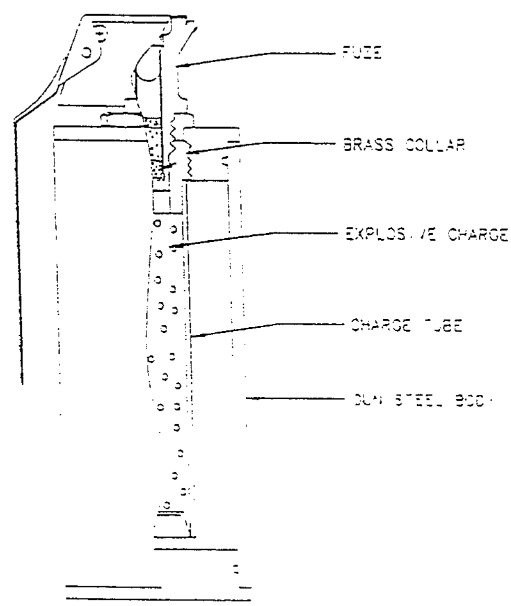
Concept and Design Phase

After obtaining the L8 components, it was determined that a stingball was feasible using the existing components. The decision to proceed was based on previous experience and manufacturing practices that are used in the production of the Defense Technology #15 Stinger Grenade and the #25DD (Distraction Device). Even though both munitions utilize a flash composition of different charges, a black powder charge was used based on its' relatively stable handling condition. This provided a quick demonstration of the feasibility without having to endure the rigors of extensive loading and handling concerns.

#15 STINGER



#25 D.D.



The static tests proved that the materials used for the L8 would be sufficient to test and demonstrate the concept and design. As expected, the black powder charge produced a much slower and lower sound report than all of the flash charges. The flash powder produced a much more brilliant and thunderous burst. Upon examination, the black powder appeared to only split the rubber bodies or remain mostly intact with only a small section removed, whereas the flash charges seemed to shred the rubber bodies into pieces no larger than a quarter. A similar observation was made in reference to the charge tubes, where it was not uncommon to find larger pieces with the black powder and no sign of the tubes when the flash powder was used. However, as the performance criteria for this munition have not been completely established, the black powder was not eliminated from further testing.

The launch test demonstrated a linear launch distance of approximately 60 to 70 meters with no explosive charge. Because the standard propellant charge and delay for the L8 was used, once the explosive charge was added, the munition detonated approximately one and a half to two seconds after launch, at a distance of roughly 30-40 meters. The munitions produced an aerial burst at a height of 7 to 12 meters. This demonstrated that an aerial distraction device is achievable using the existing weapon platform and the standard material for the L8.

Once the function of the device was tested and proven, the balls were added to determine if the material that the rubber body is molded with was acceptable, and provided an adequate dispersion pattern. The black powder charge showed similar rupturing of the rubber body when detonated, as recorded earlier, which did not appear to consistently distribute the balls evenly. However, the flash charges all appeared to distribute the balls more evenly, with the larger charges seeming to scatter the best. This seemed to hold true with both calibers of balls, with the only exception being that the smaller caliber of balls obviously allowed for a greater distribution and significantly more area of coverage, i.e. 50 vs. 450 projectiles.

With the addition of the rubber balls, the launch distance decreased slightly to around 50 to 60 meters. However, the aerial detonation distance and height remained roughly the same at 30 to 35 meters and 7 to 12 meters high. Once again, the flash composition produced a markedly greater burst and distribution of the balls with a significant increase in coverage area with the smaller caliber size. The munitions seemed to consistently distribute the rubber ball projectiles, however, the launch base was more unpredictable in where it landed, with some traveling as far as 20 to 25 meters from the point of detonation.

Performance Review

The attempt to record velocities of the rubber balls with a chronograph was unsuccessful, as the concussion from the detonation prevented proper readings. Furthermore, the high speed footage of the static tests obtained at the mid-point review also had limitations. The 15 gram flash charge produced a burst that prevented tracking of the projectiles. However, velocities of the projectiles were estimated for a 12 gram flash charge to be 750 feet per second. This was determined by tracking the projectile over three feet which took 0.004 seconds. Unfortunately, only one velocity determination was calculated.

The sound report generated during the noise level testing produced an average rating of 173.7 decibels at 10 feet. This level is consistent with current diversionary and distraction devices used by the law enforcement community. Dispersion patterns for the rubber projectiles are scheduled to be conducted. A test arena will be constructed around a static launch stand to measure the dispersion pattern and distribution of rubber balls upon detonation.

Safety review

An Interim Hazard Classification (IHC) has been obtained, which will allow for shipment of these munitions until December 4, 1998. The proper shipping classifications are as follows:

DOD Hazard Class/Div/SCG: 1.3G
DOT Hazard Class: 1.3G
DOT Label: Explosive 1.3G
UN Serial Number: 0318
DOT/UN Proper Shipping Name: Grenades, Practice
DOT Container Marking: Grenades, Practice
UN 0318
NSN: 1330-00-D01-0492
Net Explosive Weight: 0.0386 lbs (0.0175 kg)
Net Propellant/Pyrotechnic Weight: 0.0
Net Explosive Weight for QD Determination: 0.0386 lbs (0.0175 kg)

While safety evaluations of these specific munitions have not been carried out, information is available on similar products that may provide valuable insight. Defense Technology has conducted research on some of their products that either utilize the same projectiles (0.32 and 0.60 caliber rubber balls) or the same explosive composition (flash powder). Blunt impact data is available for both calibers of rubber balls by various evaluation methods. These projectiles have been impacted into modeling clay, gelatin, polystyrene foam, and a biomechanical surrogate 3-Rib Structure developed by General Motors.

Impact measurements have been taken for these projectiles at velocities ranging from 51 to 1150 feet per second for the smaller balls and 200 to 1200 feet per second for the larger balls. All evaluations appeared to support the use of these projectiles as a less lethal alternative. However, at high velocities or close distance, they may be lethal if impacted into the head and or ocular region. This also raises the question about what is the level of acceptability. The intent of less lethal is that under normal conditions and use, a lethal outcome would be a rare and unexpected result. The loss of an eye, for instance, would be a very unfortunate occurrence, however, it would none the less be considered a less lethal application. For this reason, a clear understanding of acceptability needs to be defined.

Further research has been conducted on the performance of the flash composition as it relates to the sound report and flash generation. The 15 gram flash mixture is used as the explosive charge for the #25DD produced by Defense Technology. Independent testing was conducted during the design of this product that determined that this formulation and charge generated a sound report of 175 dB at five feet, along with a 2.4 million candela flash rating, which is consistent with the sound levels recorded for the 66mm stingball.

Effectiveness/Desired effect

These projectiles have been used extensively over the last five to ten years in less lethal applications by the law enforcement community. They have been deployed in a variety of methods ranging from 37mm and 40mm munitions, 12 gauge shot shells, and hand-held stingball grenades. These munitions have been deployed as method to deal with non-compliant and or violent individuals by routing or moving them, thus promoting areal denial. The primary objective of these munitions is not to incapacitate these individuals, but rather deter them from unwanted actions or prevent access to certain areas.

CONCLUSION

The research and testing was successful in that the concept and design modification was proven to be feasible, which produced a viable solution to fill the void as an extended range less lethal standoff. The 66 mm Stingball is unique in that it combines a mechanism to disperse rubber balls that cause a stinging sensation upon impact, with that of a sound or diversionary device. The intent is not to incapacitate the individuals but rather rout or move them, thereby maintaining a safe stand-off distance. Those individuals not impacted by the rubber balls will still be effected by the sound report of the device. This combines the effect of a physiological along with a psychological response. This combined effect is a useful tool in dispersing crowds in a less lethal manner, while providing the stand-off needed to ensure the safety of the soldiers, and in doings so, the safety of the combatants as well.

RECOMMENDATIONS/ FOLLOW-ON

Effectiveness/Desired effect

One of the most significant areas of review should focus on establishing the desired effect of the munition. Is the intent merely area denial as has been assumed, or incapacitation? Without this criteria, the effectiveness and safety review can not be completed. Areas of focus should include a level of acceptability in relationship to injury and lethality, and also performance.

Performance Review

When evaluating the performance of these munitions, several variations and modifications have been tested. By modifying the delay and or the propellant charge these munitions can be fired at greater or lesser distances, and may also be aerially detonated or provide ground bursts. Obviously, ground bursts would have a greater possibility of causing injury by landing on or in close proximity to an individual or materials that may cause greater secondary effects such as flammables and combustibles. As has been stated in this report, there were two variations of balls that were used in this study. Benefits and limitations should be associated with the use of each. Lastly, while the intent of this project was not to rely on the use of chemical munitions, that option is readily available, should the focus change.

Safety review

As with most endeavors, one of the most critical evaluations is that of safety. Levels need to be established for the soldier, as well as that of the combatant. As mentioned, a level of acceptability of injury or lethality needs to be determined in order to adequately establish a safety rating. Further considerations should be given to expanding upon the IHC's that have been received, and focusing on long term storage and transportation.

Non-Lethal Laser System for Sniper Detection via Optical Augmentation[a]

S. Z. Peplinski[b] and C.D. Lindstrom, Lt., USAF[c]

Abstract

Sniper detection is a challenging and important task for military personnel in hostile combat environments as well as in peace-keeping missions. Laser systems offer a potential advantage over other non-lethal systems by exploiting the retro-reflection, or optical augmentation (OA), inherent from optical systems. The U.S. Air Force Research Lab (AFRL) has recently begun characterizing the return from various optical systems of interest, specifically rifle mounted optical sighting scopes. In parallel with the OA characterization laboratory, we have constructed a prototype OA detection system for validating the laboratory measurement in the field. Results of our OA characterization and field measurements will be presented along with a description of the lab and prototype system. Particular emphasis has been placed on the fact that this is a non-lethal, eye-safe system and application.

I. Introduction

Snipers, sniper rifles and sniper riflescopes are as diverse as the applications for which they are used. A rooftop urban sniper can use a hunting rifle equipped with a good optical sight. The U.S. Marine Corp. M24 sniper weapon system (SWS[1]) uses a 10x42 Leuphold Ultra M3 telescopic sight for daytime sniping and has an effective range of 1000 yards. The Russian Dragonav SVD equipped with a PGN-1 image intensified night scope has a range of 400-500 yards and the heavy long-range barrel Cuban made Mambi[2] sniper rifle is designed for downing helicopters.

To meet the diverse tactical ranges, targets, target motion, and sniper preferences riflescope manufacturers offer a large selection of scope magnifications, reticle features, cross-hair colors and illumination features. However, from a sniper detection standpoint the most critical feature is the design of the sniper scope reticle. Reticles can be grouped into three categories: metal wire type of cross hairs, etched or coated glass substrate reticles and projection reticles. It is the goal of the U.S. AFRL to evaluate a large enough sample of sniper scopes from each of these three categories to develop the ultimate sniper detection system, one that is based on OA technology. Due to the infancy of this program only the metal cross-hair type of reticle has been evaluated both in the laboratory and in field tests. The results of these tests will be presented within the body of this paper along with a description of the AFRL OA laboratory and laser field range. Based on the preliminary results, plans for follow-on activities will also be presented.

II. OA Concept

Optical augmentation (OA) is the term for the use of lasers in detecting retroreflections from optical and electro-optical systems. The common term is the cat's eye effect. The OA detection approach consists of 3 elements: a laser illuminator, an optical target and an

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imaging receiver. The laser is used to illuminate a scene containing a camouflaged sniper who is equiped with sniper rifle and optical sighting scope. In Figure 1 a portion of the laser beam enters the objective lens of the sniper scope and comes to focus in its image plane. The riflescope's image plane is coincident with the placement of the scope's reticle or cross hair. Any and all optical, metallic or coated surfaces have some inherent reflection. A collimated laser beam will focus on the reticle or cross hair and a portion of the laser beam will be retroreflected (like a corner cube) back out of the riflescope in the direction of the transmitter. Due to diffraction effects the return signal will be a far field diffraction pattern with some type of spatial intensity distribution. The angular extent (or spatial distribution) in the plane of the OA detection system's receiver is measured in micro-radians and is called the bistatic angle.

To exemplify the appearance of the radiation pattern in the plane of the OA detection system a composite picture was made by overlaying the scope's 9x boresight OA pattern, as measured in the laboratory with the Battlefield Optical Surveillance System (BOSS[3]) gimbal mounted OA detection system. The result is shown in Figure 2. As can be seen the retroreturn is quite large in angular extent. The specific radiation pattern is dictated by the scope aperture diameter; laser wavelength, type, geometry, texture, and reflectivity of the focal plane surface; the interrogation aspect angle; the focused beam location inside the scope; the proximity of the reticle/cross-hair to the focal plane of the scope; and target range.

The OA return from the covert surveillance system shows up as a bright flash of light on the BOSS video monitor. The bright flash indicates not only the presence of the covert system but also pinpoints its location. If the OA receiver is equipped with a zoom lens, as is the BOSS, the interrogator can zoom in on the flash for target identification. Should the operator confirm the presence of a sniper the target location and grid coordinated is recorded and passed on to the commander for follow up action. Since the BOSS is a non-lethal laser system no active laser countermeasure is used against the sniper.

Still frame images of actual OA signals generated by a metallic wire-type of cross hair and recorded by the BOSS camera during recent night operations are shown in Figures 3 to 6. In Figure 3 a camouflaged sniper, located at a range of 1.2 km, is pointing his rifle far left of the BOSS. At this range with no active laser illumination, the scene is nearly black. With illumination and an image intensified camera details in the terrain can be observed but the sniper can not be identified. However, when the laser is activated and the sniper is boresighted to the BOSS a bright flash of light is clearly visible in the camera's field-of-view (FOV). The results are shown in Figure 4. Even when the sniper looks away and the laser illumination comes to focus at the edge of the sniper's FOV a strong retroreturn is observed. The edge of the FOV condition is shown in Figure 5. For this particular sniper scope OA returns were observed well outside the device FOV. These low-level OA images are shown in Figure 6. The field trials, albeit not all encompassing, demonstrated the utility of OA for sniper detection and location.

III. OA Characterization Laboratory

The AFRL OA laboratory, shown in Figure 7, was developed to perform detailed, parametric and quantitative OA analysis as part of the sniper detection effort. It can also be used to evaluate other optical and electro-optical systems. The quantitative lab data is used to predict (and/or correlate with) the qualitative results obtained during field trials. The lab setup is an un-obscured Fourier Transform Range Simulator (FTRS) geometry. The setup serves as, both, the laser interrogator and as the OA receiver. The major elements are a laser, 2-axis computer controlled scan mirror, off-axis parabola (OAP), imaging receiver, power monitor and a PC based data acquisition & processing station. In the transmitter mode the raw pencil-like laser beam is spatially filtered then expanded to provide uniform illumination over the entire

target aperture. The target, like a sniper scope, is mounted in front of the scan mirror and is interrogated in a raster like-pattern. At each interrogation angle the scan mirror illuminates the sniper scope and simultaneously directs the retroreturn back towards the spatial filter. Prior to the spatial filter a beam splitter redirects the retroreturn towards the FTRS sensor where the 2-D OA diffraction pattern is recorded with a CCD camera. The entire image is then digitized and saved for processing. For a typical 128x128 position raster scan 3.7 Gbytes worth of images are acquired and saved. A library of retroreturn images is being established for each device.

In addition to saving the OA images, the station provides a series of 2-D peak differential cross section (PDCS) and average optical cross section (OCS) scan maps for different transmitter/receiver geometries and ranges. The maps can be displayed in intensity, contour and 3-D mesh plot formats. More sophisticated post processing can yield useful information regarding the transmission and the scattering efficiency of the scope optics.

IV. Prototype OA Detection System

The BOSS, shown in Figure 8, consists of a suite of visible, near infrared (NIR) and long wave infrared (LWIR) sensors for passive and active day, low-light level and nighttime battlefield reconnaissance and sniper detection. The sensors and illuminators are distributed between two 2-axis gimbals mounted on a High Mobility Multipurpose Wheeled Vehicle (HMMWV). A comprehensive description of the BOSS is included in an accompanying paper entitled " BOSS: A HMMWV Mounted System for Non-Lethal Point Defense".

The lower gimbal contains a foreward looking infrared (FLIR) sensor while the top gimbal consists of two laser illuminators, which can be turned on independently by the operator, and a combination day/low light level video imaging system. Depending on the ambient light level conditions the operator can select the day only video system or remotely switch to an image intensified camera mode. From an OA perspective the laser illuminator establishes the line of sight to the target (i.e. boresight) and the receiver (i.e. camera) can be considered radially offset from boresite. This type of OA detection is considered to have an offset geometry. The other two types of OA transmitter/receiver geometries are: centrally obscured and un-obscurred. The centrally obscured geometry is where the laser illumination beam is made coincident with the camera's line of sight using a very small turning mirror. This is similar to a Newtonian telescope. The third, unobscured, geometry may be the most optimum design yielding the highest sensitivity for the least amount of laser illumination. Whereas the 1st two geometries are more likely to be considered strap down systems, the 3rd geometry is more of a custom design and hence is more costly to build.

Field trials were conducted with the BOSS illuminating the target scene at 3 ranges (300, 500 and 1200 meters). At the target range the riflescope was mounted either on a 2-axis motor driven pan & tilt head (see Figure 9) or manually aimed by a sniper (see Figure 10). The pan & tilt head was used to precisely position the aimpoint of the riflescope so that the interrogation beam struck different regions of the focal plane. The particular riflescope used contained a metallic wire type of crosshair. Prior to beam irradiation the pan & tilt stage was leveled using a surveyor's level and the riflescope was clocked to assure that the vertical and horizontal crosshairs were coincident with the pan/tilt head's elevation and azimuth drive directions.

During active laser illumination the riflescope was oriented so the beam struck boresight (the intersection of the crosshairs). Then the scope was moved in elevation so the focused laser spot traveled along the crosshair out to and beyond the vertical limit of the scope's FOV. The process was repeated for the azimuth direction. The ability to detect the riflescope when the focused spot was off of the crosshairs was also evaluated. Data was

obtained for the upper and lower right quadrants of the scope's FOV. During active illumination the BOSS video signal, showing the OA retroreturn, was video taped. The video was date & time stamped and a test historian recorded a log of events. Radio communication was maintained between the sniper, the BOSS, and historian. Special note was made when the beam was at boresight, ½ way to the edge of the FOV, at the edge of the FOV, outside the riflescope's FOV and in the two quadrants.

In addition to controlled pan & tilt tests the ability to detect an actual sniper, holding the rifle and manually pointing the riflescope in the general direction of the BOSS was evaluated. Video showing the variations of the OA signature as the sniper took aim at the BOSS and at targets within a several hundred meter radius of the BOSS was recorded.

The field trials were conducted under different laser illumination levels in attempt to determine minimum irradiance levels while maintaining OA detection, maximum target detection range, and laser eye safety conditions. During the entire mission the irradiance level at the target site was monitored and recorded with a precision, calibrated, power meter. Though OA detection was achieved with eye-safe irradiance conditions all personnel at the target site wore laser safety glasses with appropriate levels of optical density.

V. Lab & Field OA Results

Laboratory measurements were conducted on the same riflescope that was used for field tests. These measurements were conducted prior to field tests in an effort to predict and plan for the operational tests. High-resolution scan maps were acquired by interrogating the riflescope in 128 (El) x 128 (Az) positions over a 6 (El) x 6 (Az) degree field-of-regard. The resultant PDCS scan maps are shown in Figure 11 for different scope magnification settings and for different receiver geometries. These maps contain a wealth of engineering, scientific and operational data that must be carefully interpreted. The bright regions on the map represent regions within the riflescope that generate high retroreturns. The brightness of the pixels is proportional to the OA signal strength. Figures 11a and 11b represent the resultant scan maps for the case where the search region for peak cross section extends the entire FTRS receiver FOV. Figure 11a and 11b represent the scan map for the 3x and 9x scope magnification, respectively. These maps show that raster scanning the scope creates an OA map of the riflescope's focal plane and that the regions of high retroreturn correspond to the scope's metallic crosshair. The maps also show that the angular detection range is governed by the scope magnification. Since lower magnification implies wider scope FOV, the sniper can be detected over a wider interrogation angle. When the sniper is zooming in on his target, the detection angle is reduced proportionally.

To evaluate the effect of transmitter/receiver geometry saved images, acquired during the 9x magnification condition, were processed for a monostatic receiver (modeled as a 3 x 3 pixel search region about the FTRS boresight) and for the BOSS offset geometry. The PDCS maps corresponding to these two geometries are shown in Figures 11c and 11d. The maps look similar to the map generated by the entire FTRS FOV search region (Figure 11b) but the detail is not quite the same and the amplitudes of the PDCS are different. The differences between the maps are be governed by the riflescope diffraction pattern and intensity as a function of bistatic angle.

This is more clearly seen in Figure 12 where the mean OCS maps are shown for different target ranges. Figure 12 consists of six FTRS outputs grouped into 2 sets. Each set represents data for a given range; 300, 500, and 1200 meters. The left most output in each set is the FTRS image of the bistatic diffraction pattern obtained from the riflescope's boresight position. Superimposed on it is a white square indicating the apparent angular size and location of the BOSS's off-axis receiver geometry. The area inside the white box represent the portion of the

retroreturn that is intercepted by the BOSS receiver at that range. The right figure in each set represents the mean OCS scan map for that range and apparent receiver size. The mean scan map is presented as a meshplot (top of the right figure) and as a 2-D intensity image (bottom of right figure). The results of Figure 12 show that the geometry of the OA detection system and the shape of the diffraction pattern govern the mean OCS of the riflescope.

The data for the 300 m range is shown in Figures 12a - 12b. At this close range the receiver appears to have a large angular extent but because of the offset it intercepts only the edge of the scope's diffraction pattern. The mean OCS scan map for the BOSS. at the 300 m range, is shown in Figure 12b.

At 500 meters the angular extent of the receiver reduces in size and the offset becomes smaller, as can be seen in Figure 12c. This search region contains pixels with higher signal strength which results in a brighter mean OCS scan map (Figure 12d).

As the target range increases the search region approaches, and at infinity converges, to OA detection system's boresight position. The long range, 1.2 km data is shown in Figures 12e and 12f. The OA signature from the crosshairs is starting to fill in the map is beginning to look more like the monostatic PDCS map in Figure 11d.

I. Future Plans

Based on the successful laboratory and field tests the laboratory effort will be expanded to speed up data acquisition and post processing. In addition a reconfigurable breadboard OA field table will be developed to evaluate different geometries & wavelengths. AFRL is actively seeking collaboration, under a Cooperative Research and Development Agreement (CRADA), with scope manufactures to perform OA characterization and field tests various riflescopes.

VII. Summary/Conclusion

The laboratory and field tests clearly indicate that the application of OA to detecting snipers is a viable technology and that further research and development into this approach is warranted. However, any field tests must be coordinated with OA laboratory analysis. The data clearly indicates that, prior to performing field OA detection tests, the OA signature of the target should be characterized in a benign laboratory environment for the particular OA detection's transmitter/receiver geometry and target range.

The OA laboratory measurements also provide useful engineering data regarding the source of OA retroreturns and the scattering efficiency of the riflescope's optics. This area of investigation should also be exploited. The field test results tracked the laboratory scan map data. However, a few positive anomalies were observed which warrant further investigation.

Acknowledgements

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2 *Albuquerque Journal, from the Associated Press, 3 December 1996*

3 *W.T. Cooley, Capt., USAF, T.P. Davis, Lt., USAF, J.M. Kelly, "BOSS: A HMMWV Mounted System for Non-Lethal Point Defense", ADPA/NSIA Non-Lethal Defense III Conference, 25-26 Feb 1998.*

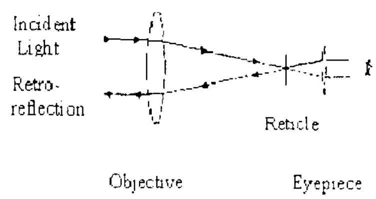


Figure 1: OA Concept

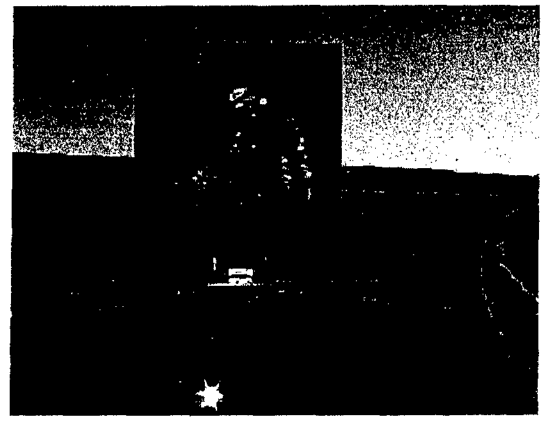


Figure 2: OA Diffraction Pattern

Figure 3: Sniper Looking Far Left

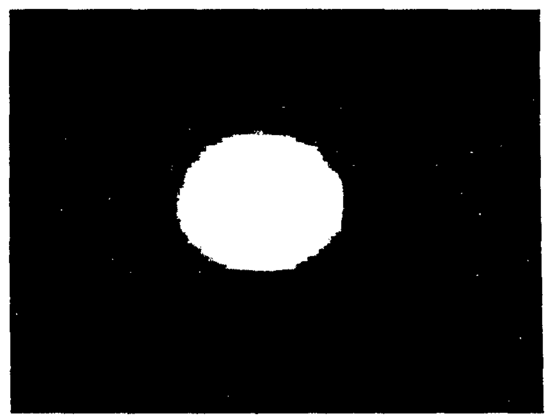


Figure 4: OA from Sniper's Boresight

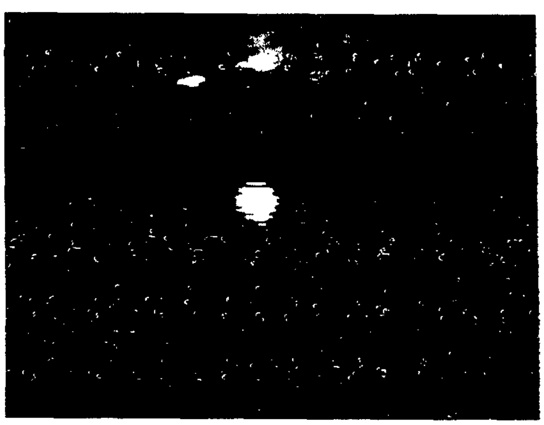


Figure 5: OA from Sniper's Edge of FOV

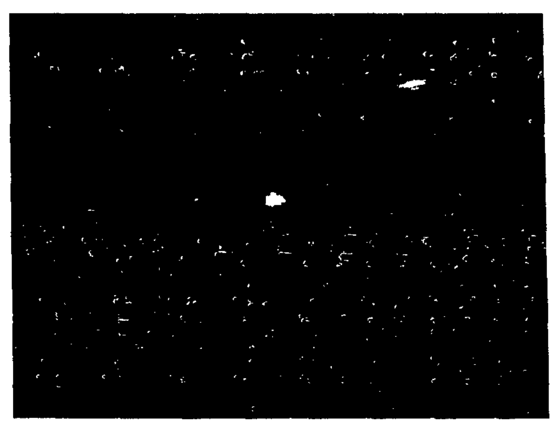


Figure 6: OA from Outside Sniper's FOV

Figure 7: OA Lab Setup

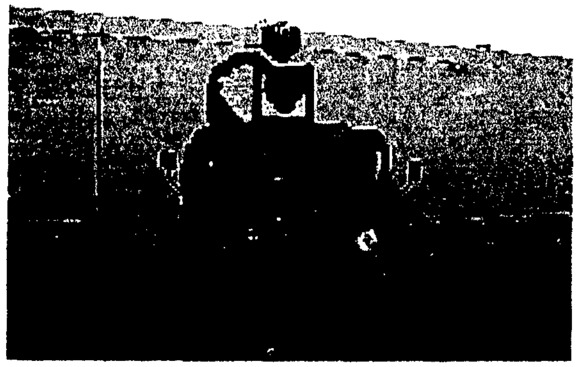


Figure 8: BOSS

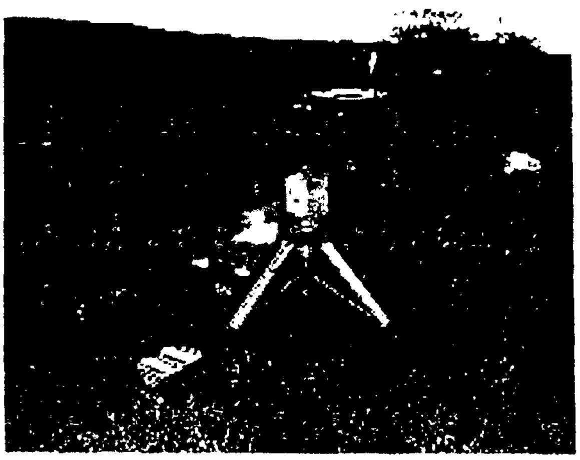


Figure 9: Rifle and Scope Field Setup

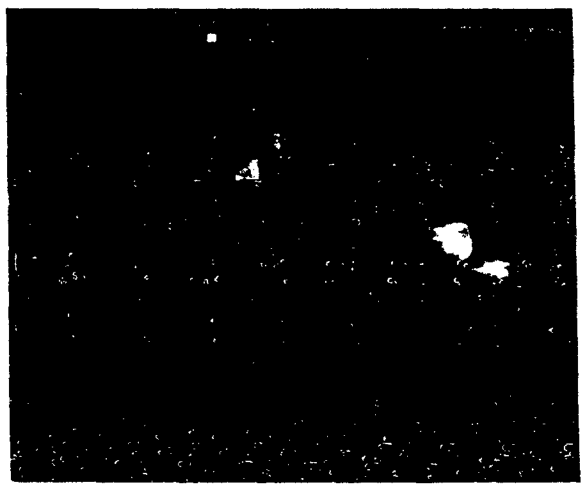


Figure 10: Sniper with Rifle and Scope

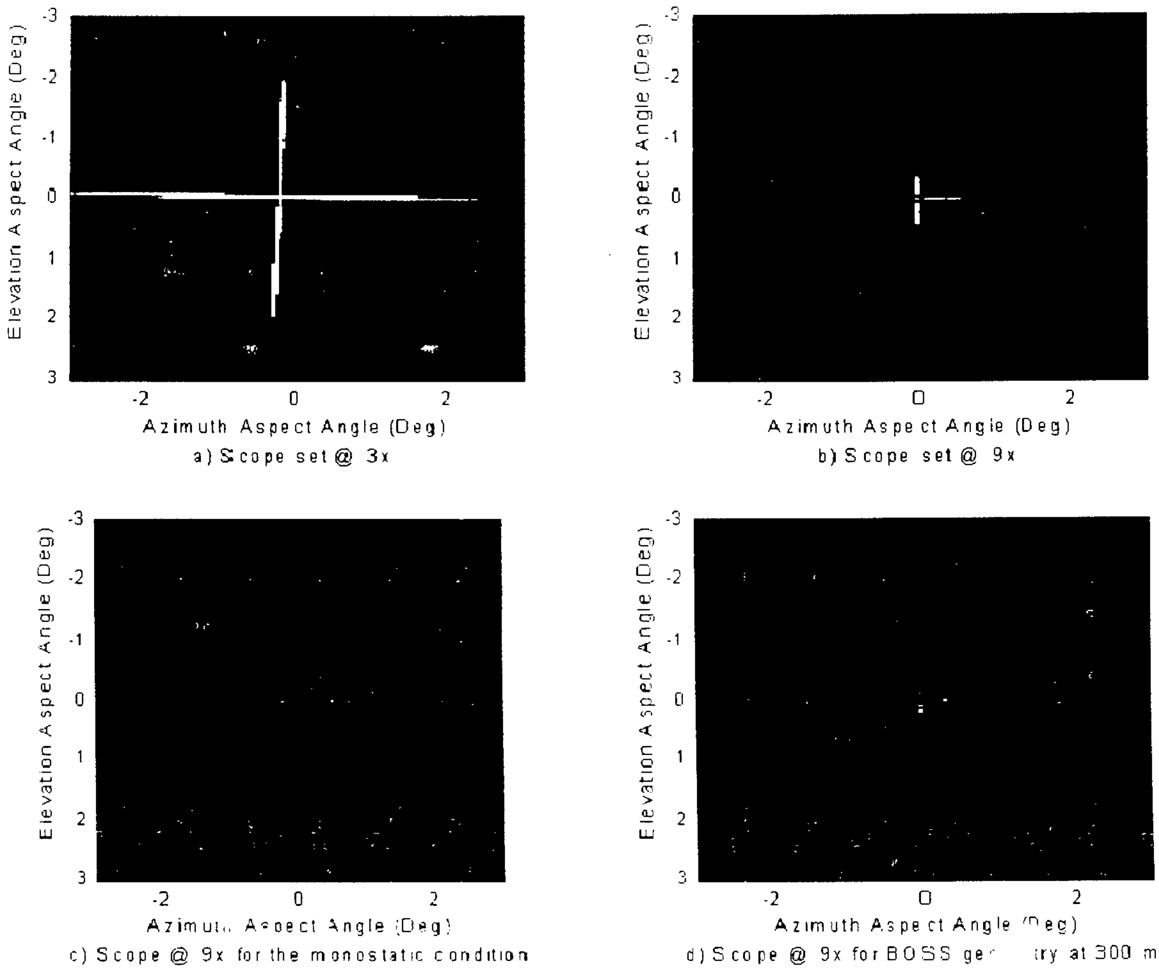
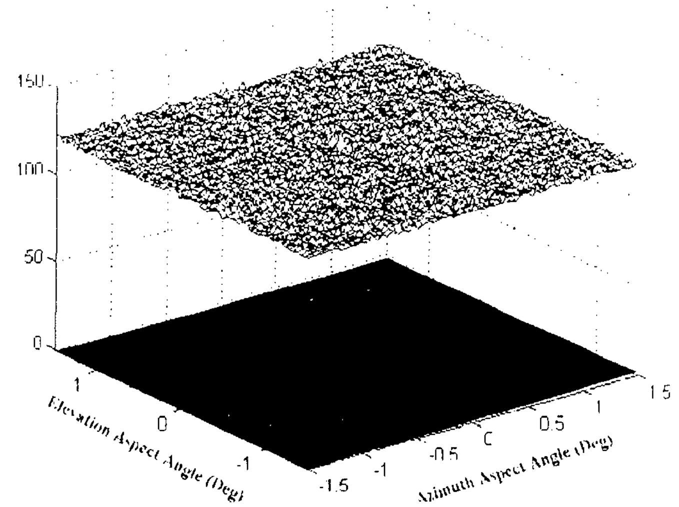
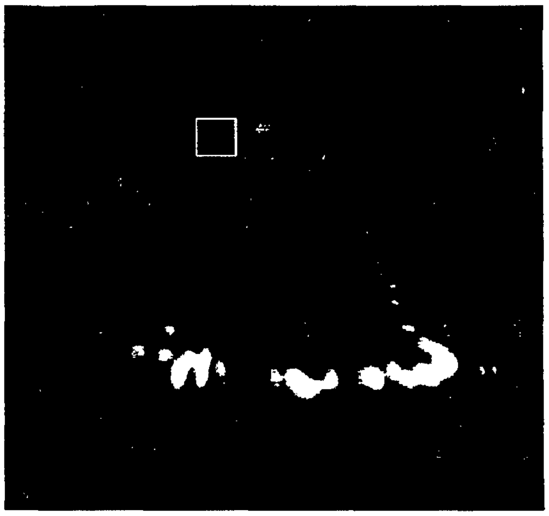


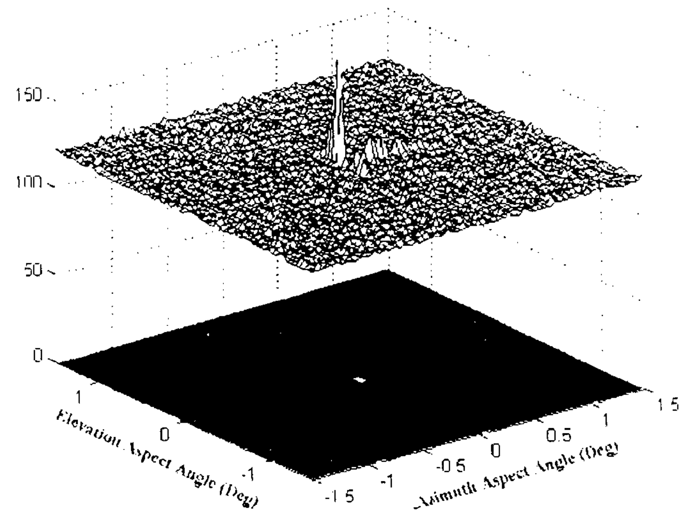
Figure 11: Various PDCS maps for same rifle scope



a) **BOSS Bistatic Search Region**

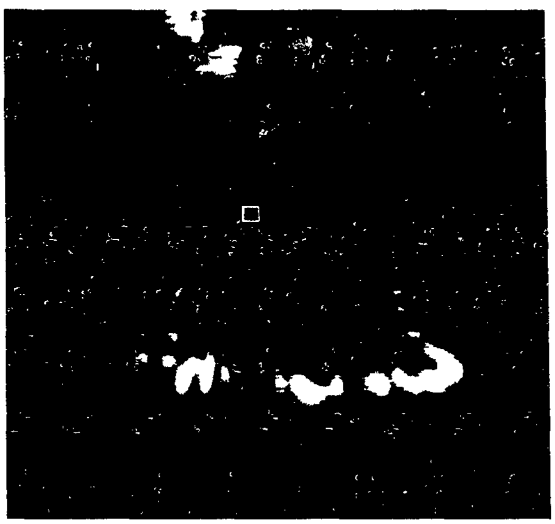
b) **Mean OCS Map @ 300 m**

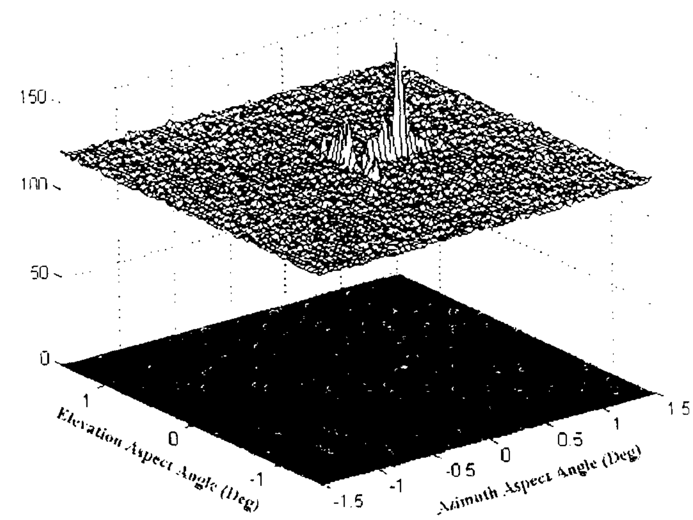




c) **BOSS Bistatic Search Region**

d) **Mean OCS Map @ 500m**





e) **BOSS Bistatic Search Region**

f) **Mean OCS Map @ 1.2 km**

Figure 12: Average OCS maps for BOSS geometry @ various ranges

USMC Small Unit Leader Non-Lethals Training System

Main Topic

A team of researchers and engineers in the Simulation and Systems Engineering Section at Southwest Research Institute (SwRI) is working on the second phase of a project for the United States Marine Corps that trains Marines in decision-making with respect to the use of non-lethal munitions in peacekeeping and crowd control operations. The Marines have several requirements for training their personnel for Military Operations Other Than War (MOOTW). In particular, SwRI is contracted to create a scenario-based, visual training system that gives Marines practice in making decisions under realistic conditions about the deployment and use of non-lethal munitions in a peacekeeping operation. The first phase of this project, called the Small Unit Leader's Non-lethals Trainer (SULNT), concluded with a successful test and demonstration at Camp Pendleton, California at the Emerald Express conference in April 1997. A follow-on project has been awarded to SwRI for additional tasks.

The SwRI team created a visual, scenario-based computer simulation that is highly interactive. The simulation includes models of the effects of specific non-lethal munitions in the Marine Corps arsenal and also of crowd and mob activities. Using the simulation, students are able to demonstrate their knowledge of proper rules of engagement, procedures for dealing with crowds and mobs, and their ability to make decisions about the appropriate level of force needed to control, contain, or disperse crowds and mobs. The Marine trainees can be confronted with several scenarios at once and by multiple crowds as large as 500 people each. Crowds move within a simulated urban environment along instructor-defined pathways and respond not only to actions taken by Marines but also respond autonomously to actions by other simulated crowds and to the passage of time. The trainees are able to deploy simulated barriers and fortifications and are constrained by realistic levels of ammunition, line of sight targeting, movement rates, and squad strength. The simulation uses both historical and generic ethnic, political and religious groups to confront the Marine trainees, and the confrontations take place within one of three different urban environments. The Marines are stationary for the most part and are in a reactive mode; however, they are free to move throughout the environment during the course of a training scenario.

The SULNT system is highly visual, with a Windows-like graphical user interface (GUI) and realistic 3D models of Marine personnel, checkpoint position defensive barriers, civilian crowds, urban areas, and surrounding countryside. The user interface also provides the trainee with textual descriptions of events, his orders and background information, rules of engagement (ROE), and controls for movement and interactive commands within the simulation. The trainee receives verbal feedback of scenario events and crowd actions/reactions from an electronic speech synthesizer and audio sound effects. The operational computer platform is a Silicon Graphics (SGI) Octane workstation with Maximum Impact graphics.

Prior to a training session, an instructor creates a new scenario for training (or edits an existing scenario) using a unique set of user interface displays and controls designed specifically for this purpose. A separate set of interface controls enables an expert user to alter some of the underlying simulation model control parameters such as munitions effects data. After the instructor has created a scenario, the trainee initializes his forces—a standard Marine rifle squad along with two designated marksmen—at a checkpoint location designated by his instructor. The trainee arms his simulated squad with lethal and non-lethal munitions that are part of the current Marine Corps arsenal. The effects of the munitions are modeled to first-order accuracy based on data provided to SwRI from the Naval Surface Warfare Center in Dahlgren, Virginia.

Training scenarios are run from a separate user interface screen, and during a scenario the trainee is faced with the activities of one or more simulated crowds. The crowds are modeled from data collected from experts, from scientific and technical literature, and from information gathered from Marine Corps and other government sources. The crowd model is dynamic and based on empirical knowledge gathered by experts. Each crowd is characterized by a series of attribute values which together comprise a crowd profile. Attributes include fanaticism, arousal state, prior experience with non-lethal munitions, and attitudes toward the Marines (fear, respect, anger, etc.), among others. The attribute profiles are linked to

a behavioral model that generates crowd activities during the course of a scenario such as demonstrations, carrying signs, throwing stones, and so on. The link comes through a set of Boolean relations shaped by our understanding of the literature and validated by our experts. Crowd movement is determined along initial paths defined by an instructor. However, actions taken by the trainee and other scenario events can influence crowd movement as well.

In a typical scenario, the trainee deploys his squad in fire teams, reserves, and designated marksmen. During the course of a scenario, he receives textual and audio information regarding crowd activities; and he can view a graphical display that shows either a 3D ground-level view or 2D overhead plan view of the modeled urban area. The 3D ground-level view provides the trainee with an accurate visual representation of the urban environment from any point on the ground, including buildings, streets, Marine personnel, checkpoint defenses, and civilian crowds. The trainee can also change his viewpoint to gain a better understanding of the situation at hand by moving freely about the environment in this view using a simple set of user interface controls. The 2D overhead plan view provides the trainee with a flat earth, god's-eye view from a static altitude above the urban area. In this view, the 3D models of people and defenses are replaced by 2D map symbols and movement within the scene is restricted to the four standard cardinal directions: north, east, south and west. Both graphical views are updated in real time as the scenario progresses, and the trainee can switch between either view at any time.

During a scenario the trainee can move his troops, issue verbal orders to the crowd, and order lethal or non-lethal fire. As in the real world, the supply of clips and ammunition is limited, there are line of sight and range restrictions, and munitions effects are probabilistic rather than absolute. The actions taken by the Marines affect crowd behavior in several ways. Some crowds can be dispersed by a simple verbal command, whereas other crowds disperse only with swift and heavy action from the Marines. The Marines can be affected by crowd behavior and activities as well. Squad units can suffer casualties from attacks by armed hostile crowds or by friendly fire from other squad units.

Each training run is independent and the outcome dependent on Marine actions and inaction. In other words, a trainee can run the same scenario several times and each run can result in a different outcome. Successful trainees read their background and orders, study their ROE, and make decisions based on proper procedures. At the conclusion of a successful run, the trainee receives a good report and other positive feedback. On the other hand, if rules are violated, the trainee is presented with verbal reports of bad outcomes such as an unacceptable number of civilian casualties, angry superior officers on their way to admonish the trainee, or a television news program reporting his actions in a negative manner.

The SULNT system also provides an after-action review capability that allows a trainee and his instructor to replay a scenario run in its entirety with all actions preserved. The replay can be paused, fast forwarded, or rewound to a specific time so that an instructor can make a teaching point. Scenario after-action reviews can also be saved for re-use in a group instructional setting.

Trainee options are based on USMC procedures and were validated by the Marine Corps experts including the project officer who leads the USMC non-lethals effort for the Marine Corps Warfighting Lab. This officer had direct personal experience with peacekeeping operations and non-lethal munitions in Somalia. In addition, SwRI gathered data while attending a Limited Objective Experiment (LOE) as an observer at Camp Pendleton in July 1996. The LOE was a three-week long field exercise in which Marines were trained in the use and tactics of non-lethals. Exercises with actors simulating crowds and mobs were conducted five to six times per day. In addition, Marine Corps Reservists who are active duty crowd control officers from the Los Angeles Police Department (LAPD) and the Los Angeles County Sheriff's Department (LASD) were also in attendance.

We believe that much of our success on this project is due to the detailed up-front analysis, the active participation of our sponsor and his experts, and the iterative testing of our software. In February 1997, the system was tested with enlisted personnel from the 15th Marine Expeditionary Force (Special Operations Capable) at Camp Pendleton. For one week, the system was put through its paces by the enlisted Marines (corporals and sergeants). The Marines used the system as students in the first half of the week and as instructors during the second half of the week. Their comments and suggestions for improvement were

collected by SwRI staff and many of their recommendations have been implemented. A second demonstration period took place at Camp Pendleton during April 1997, at the Emerald Express conference. During that conference, more than 30 military personnel and civilians used the system. In October 1997, the system was also demonstrated for the Platoon Leaders school at the Los Angeles County Sheriff's Department, and comments were collected and analyzed for improvements to the system. We are currently working in cooperation with the LASD on an internally funded research project at SwRI aimed at creating a law enforcement version of the system for use by civil authorities.

During development of this training system, SwRI researchers and engineers conducted structured interviews with experts from the uniformed services and from civil authorities in addition to the published literature. It is apparent to these researchers that there are many technical training and simulation issues and concerns which overlap between civil and military groups in confrontation with large groups of people, whether those groups are friendly, neutral or hostile, and whether the groups have peaceful or violent intentions. The type of crowd is also important. Crowds can be of several types including casual crowds of people who happen to be gathered in the same place (such as shoppers); expressive crowds who have gathered for specific behaviors such as worship, dancing, or singing; and aggressive crowds which are unorganized, potentially unlawful groups (Momboise, 1969). In addition to crowds, there are also mobs and rioters who are engaged in undesirable activities and may be out of control.

In recognition of the different types of crowds and mobs and, indeed, differences in the behavior of individuals within a single crowd, the SwRI group behavior model includes several psychological variables including level of aggression, hostility toward the Marines, prior experience with non-lethal munitions, and degree of fanaticism and devotion to ethnic, religious, or political causes. There are also parameters for the degree to which a crowd may be armed. The variables are set to an initial state by an instructor and change as the scenario unfolds. Actions taken by the Marines may make a crowd more or less angry, more or less hostile, and so on. If left alone and unchallenged by the Marines, the emotional variables may also change, depending on the initial states and the degree to which the crowds are hostile to one another.

Riots, mobs, and demonstrations are far more common than is realized by the general public and have been going on in all societies and in all parts of world since civilization began. As an example, in Constantinople in 532 A.D., a conflict between the "Blues" and the "Greens" erupted with over 30,000 casualties. The underlying cause of the rioting is thought to be political and economic, but the catalyst for violence was a chariot race (Steele, 1993). At present, law enforcement officers in major US cities may be involved in public confrontations on a weekly basis and damages can accumulate into the millions of dollars. These confrontations may be as small as a bar fight that spreads onto the street or as large as a celebration riot accompanying a major sports championship (Hillmann, 1991; McGregor and Griffiths, 1995). The National Law Enforcement Policy Center has called for special training in civil disturbances "for both line and supervisory officers, as well as command personnel." SwRI has also received informal inquiries from civil authorities and from other commercial companies about the possibility of re-use (or re-tooling) of the USMC-owned software for civilian purposes.

Currently, the SwRI team is providing hardware and software maintenance support for eight SULNT systems that are being used by fleet Marine forces in a one-year training effectiveness experiment conducted by the Marine Corps Warfighting Laboratory. We are also working in conjunction with the LASD in the analysis and requirements definition phase of our research project relating to a law enforcement training system based on the SULNT.

About the Authors

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Dr. Varner is a research psychologist responsible for identifying and researching new technologies, tools, and processes that will facilitate training. She has directed and participated in projects involving virtual environments, scientific data visualization, digital video, and speech recognition technologies in training. She developed a physics-based model and visual simulation of fire and smoke under SwRI's Internal Research and Development (IR&D) program. At present, she is project manager for the SULNT program and for an internal research project in cooperation with LA County.

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Mr. Royse is a specialist in electronic systems design, integration, and testing, and has significant design and project management experience in the development of simulation and multimedia-based training systems for the USMC, USAF, and NASA.

As manager of the Simulation and Systems Engineering Section, SwRI, Mr. Royse is responsible for the development of proposals and performance of project activities which involve engineering analysis, design, and development of training systems and simulation devices. He leads a group of engineers and computer scientists developing computer-based solutions to the training and simulation problems of government and industrial clients.

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Mr. Micheletti is experienced in the design, coding, testing and documentation of software for real-time, mission-critical avionics systems, avionics maintenance procedures training systems and simulators, and battlefield operations training systems and simulators.

Mr. Micheletti has been involved in the management, analysis, design, test, and documentation of software for several multi-station, networked training and simulation systems for the US Marine Corps and Air Force. He is currently the lead software developer on the SULNT project for the Marine Corps. The SULNT is designed to train decision-making skills for squad leaders regarding the use of non-lethal munitions in urban operations other than war.

MAJOR EUGENE N. APICELLA
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Major Eugene Apicella was assigned to his current duties as an Action Officer at the Marine Corps Warfighting Laboratory in September 1995. His duties include Non-lethal Capabilities Action Officer and Action Officer, Fires and Targeting Section, Marine Corps Warfighting Laboratory.

Most recently he served as Commanding Officer, Company K, Third Battalion, Seventh Marines, First Marine Division at the Marine Corps Air Ground Combat Center, Twentynine Palms, California from September 1992 through July 1995. While assigned to 3/7, he was also the Commanding Officer of Headquarters and Service Company and functioned at the Ground Combat Element Commander, Special MAGTF Belleau Wood during OPERATION UNITED SHIELD, the final U.N. withdrawal from Somalia. A 1992 Honor graduate of the U.S. Army Infantry Officer's Advanced Course, Major Apicella has also graduated from numerous other military specialty schools including the Airborne Course and Pathfinders Course.

Personal decorations include the Navy Commendation Medal, with two Gold Stars and Combat V, the Combat Action Ribbon, the Navy Achievement Medal, and the Armed Forces Expeditionary Medal.

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A SCENARIO BASED METHODOLOGY FOR THE SELECTION OF NON-LETHAL WEAPONS

Non-Lethal Weapons System Engineering Study Team[1]
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The allocation of finite resources to develop non-lethal weapons for deployment as effective military assets is a difficult task considering that there exists a myriad of potentially promising technologies. Each proposed weapon has operational, logistical, and developmental advantages and disadvantages, which often do not appear self-consistent. Attempts to invent a common figure-of-merit often fail because it is difficult to avoid subjective criteria and evaluation. Ideally, an objective, consistent weapons selection methodology is required. We have developed a scenario based requirements methodology that allows us to highlight inter-scenario commonalties among the weapons considered. We have evaluated some thirty different anti-personnel and anti-material weapons considering over a dozen scenario based requirements including such criteria as effective range, weather susceptibility, cost, logistics and training. A selection matrix considering a requirement weight factor within a given scenario (e.g. MOUT, riot control) and performance comparison allows us to define overall weapon effectiveness within the context of the given scenario. Surprisingly, this scenario based analysis allows for an objective consensus evaluation of seemingly dissimilar weapons systems.

This system engineering approach commences with a functional decomposition of non-lethal capability and includes many subsystems, components, parts, and their tactical interactions. We seek to look for a *complete solution*, a solution that involves logistics, weapons suite, TTP (Tactics, Training & Procedures), C^4ISR, and life cycle cost. System engineering emphasizes integration from the beginning; thus avoiding stovepipes and sub-optimization. The principal of iteration in evaluating tradeoffs does not guarantee that all possible solutions are reviewed, but this scrutinizing methodology endeavors to optimize by quantifying essential criteria.

We seek an effective solution by first identifying the problem (i.e. what are the mission requirements?). Although the field of non-lethal weapon utilization is complex, crossing the spectrum of conflict (controversially the name itself stirs heated debate), a scenario driven approach helps isolate and identify the problem. Any scenario must be plausible, realistic, and relevant to the basic need (a non-lethal capability). These scenarios produce a list of broad system functions. Our analysis was based on the six scenarios from Non-Lethal Warfare Coordination Group [2]. The tactical requirements included functions such as: crowd control, incapacitate/stop crowds, stop a vehicle, and area control/denial. Actual specific requirements follow from these top-level functions. Some of these requirements will be specific to a particular scenario; such as effective range, countermeasure susceptibilities, etc. Other requirements may be common to all scenarios; life cycle cost, logistic requirements, etc.

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[1] Officer-Student members: CDR Randy Franciose, LT Phil Campbell, LT Thuy Do, LT Tim Holliday, LT Eric LeGear, LT Matt O'Neal, LT Rick Steele, USN; CPT John Hartke, USA; and LTC Margaret-Anne Coppernoll, ARNG. Faculty advisors: John Osmundsen, Xavier K. Maruyama, and Robert Harney.

[2] Non-Lethal Warfare Coordination Group, under aegis of The Joint NLW Directorate. Scenarios included a preemptive strike, riot control, peace keeping, maritime interdiction and two military operations in urban terrain (MOUT) scenarios.

Scenarios Derived Requirements	
- Effective Range	- Effective Area
- Time to Effect	- Weapons Persistence
- Penetration Depth	- Target Selectivity
- Countermeasure Susceptibility	- Weather Susceptibility
- Non Lethality	- Environment Effect
- Life Cycle Cost	- Logistics
- Training	- Flexibility

Table 1. Requirements derived from NLW scenarios.

Table 1 list the requirements derived from the six NLW Coordination Group's scenarios. In addition to the scenario requirements, certain constraints must be considered in finding a solution. Constraints can include legal and ethical issues of non-lethal weapons employment.

Using the scenario derived requirements and system constraints, current and future technologies can then be evaluated. The evaluation review process of these non-lethal technologies must be iterative in nature. The iteration spiral of this evaluation involves the integration of non-lethal technologies into a military force structure (current military force structures or possible future structures) and then modeling the force structure performance in the selected scenarios. Scenario modeling provides feedback for the next evaluation cycle until the iteration eventually converges onto an optimum solution. The fundamental steps of the system engineering approach to non-lethal warfare are illustrated in figure 1.

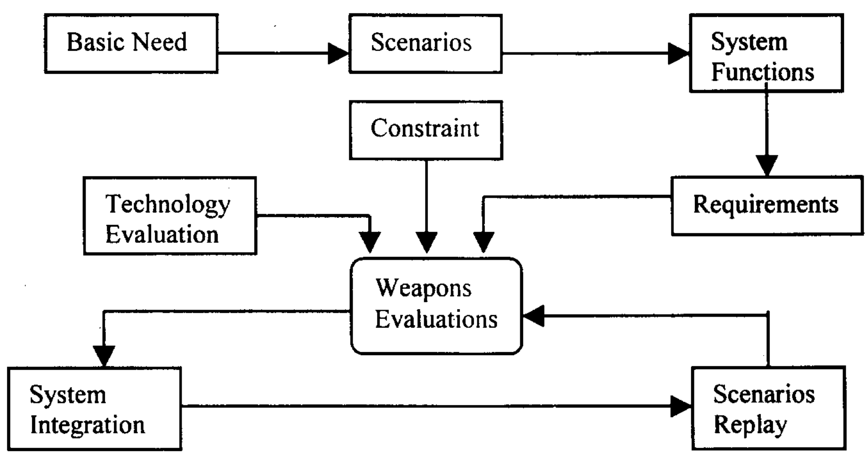

Figure 1: NLW system engineering block diagram

The evaluation methodology must be objective and consistent when applied to any weapon or weapon suite. A matrix evaluation method can be objective, consistent, and can easily be modified to many scenarios. Matrices allow quantitative results that will aide in systems comparison; furthermore, matrices can easily be expanded to evaluate technology as they arise.

The methodology of the evaluation matrix enables assessment of each non-lethal technology (weapon) in each scenario. The requirements are given weight factors (*Req WF*) to compare their relative effectiveness in each scenario. The weight factors are on a relative scale of 0 – 10 (10 high value). Each weapon is compared against each other in meeting each particular requirement and are given a weapon relative score (*Wep Relative Score*) of 0 – 10 (10 high value). The numerical effectiveness of a weapon (*Wep ReqEff*) in meeting a particular requirement is then defined as:

$$Wep\ ReqEff = (Req\ WF) * (Wep\ Relative\ Score).$$

The weapon's overall effectiveness (*Wep Eff*) in a scenario is defined as:

$$Wep\ Eff = \Sigma (Wep\ ReqEff).$$

Thus the weapon characteristics are evaluated against its peers in all requirement categories. These numerical results are good measure of effectiveness and are used for weapon selection. These mathematical relationships are illustrated in a sample matrix.

WEAPON TYPE	Eff. Range (100 m)	Flexibility
WEIGHT FACTOR	10	1
Low Energy Laser	10	7
MCCM	5	5
Baton	1	10

WEAPON TYPE	[illegible]	Flexibility	Scenario Score	Ranking
WEIGHT FACTOR	[illegible]	1	110	100.0%
Low Energy Laser	100	7	107	97.3%
MCCM	50	5	55	50.0%
Baton	10	10	20	18.2%

Figure 2. Sample matrix-illustrating weapon vs. requirement effectiveness. (MCCM = Modular Crowd Control Munitions)

The sample matrix illustrated the application of the evaluation methodology to a sample scenario where the requirement of a weapon's effective range of 100 meters was deemed very important; thus, this requirement was given the weight factor (*Req WF*) of 10. In this scenario the flexibility of the weapon was deemed not very important and was assigned a weight factor of only 1. The evaluation matrix highlights the relative strength and weakness of the three sample weapons in this particular scenario. A baton is a highly flexible weapon (scoring maximum *Wep Relative Score* of 10), but its poor effective range is detrimental to mission accomplishment. The low power laser is a weapon that is fairly flexible and has an effective range of 0 – 300 meters. The top matrix lists the raw scores of the three weapons in the scenario. The lower matrix shows the numerical results of the raw score. One can see that the low power laser is the optimal choice of the three because it was the only weapon that could effectively meet the critical effective range requirement. Although the baton scored better in the flexibility, this requirement had a weight factor of only one. The ranking column lists the normalized scenario weapon effective score for each weapon. The laser overall performance was much better than the other two.

The evaluation matrix generates numerical results that are consistent and objective. The input criteria (requirements weight factors and weapon's relative scores) are judgmental assessments. Various parties (military, political, and scientific) should be active participants in assigning the requirements relative weight factors. This is especially important because these requirements shall be the basis of weapon comparison. The defined requirements from table 1 are not all-inclusive and must be adaptable to different scenarios. The inputs of the military personnel, scientific community, and industry are absolutely critical to assigning weapons' relative scores. The weapon relative scores can readily be determined if the requirements are tangible and measurable quantities. For less "quantifiable" requirements (ie. flexibility, training, etc) where measures of effectiveness are debatable, weapon relative scores can be selectively subjective. The battlefield experiences of the military, in conjunction with input from the weapon laboratories and industry, can be utilized to make good and consistent scores. The iterative review process is essential here. Once these input parameters have been determined, the evaluation matrix methodology can be used to effectively assess any weapon in any single scenario or series of scenarios.

ANTI-PERSONNEL PHASE 1 (US FORCES IN THE STREETS - HOSTILE IN BUILIDINGS)

WEAPON TYPE	Eff. Range (>50m)	Eff. Area (room)	Time to Effect	[redacted]		Non-lethality	Cost	Flexibility	Ranking
WF	[illegible]	8	6	[redacted]		2	6	7	100.0%
LOW ENERGY LASER	**90**	**64**	54	56	**64**	12	30	56	78.7%
STUN GRENADE	40	56	60	**64**	**64**	12	54	42	72.5%
GRENADES; PEPPER, CS, E	60	48	42	56	32	12	54	49	66.7%
MID SIZE, RIOT CONTROL D	**70**	**64**	42	56	32	12	54	14	65.4%
STICKY SHOCKER	40	16	54	56	56	12	30	56	62.2%
MCCM	40	8	42	56	32	12	54	56	58.8%
STUN GUN, ELECTRIC WIRE	**70**	16	54	40	**64**	10	30	28	57.9%
DIRECTED ENERGY	**100**	24	36	48	**64**	14	6	21	54.6%
STUN GUN, ELECTRIC FLUI	**70**	16	54	40	40	10	30	28	54.3%
ACOUSTIC JAMMING	10	16	54	56	32	10	30	21	42.5%

Figure 3. MOUT scenario matrix.

This scenario matrix applies to a military operation in urban terrain (MOUT), in which a US platoon must stop inter-clan fighting. The clans are fighting between buildings and there are also noncombatants present. The scenario derived requirements that are most important have weight factor of eight or greater, and are critical. If a non-lethal solution is possible in this scenario, it must be effective for these critical requirements. We have defined the requirement selection cutoff as any weapon numerical effectiveness score of 64 or greater (indicated by large, bold numbers). This cutoff value was chosen based on the product of *Wep Relative Score* ≥ 8 and *Req WF* ≥ 8. The matrix shows that no single weapon would be effective in accomplishing the mission. A combination of the low energy laser and stun grenades could achieve all four critical mission requirements. Despite the impressive effectiveness of the directed energy weapon in the effective range requirement, its poor performance in the other requirements makes it overall ineffective in the scenario.

MAN PORTABLE	
TOTAL SCENARIO SCORES = 5050	
WEAPON TYPE	
LOW ENERGY LASER	73.9%
STUN GRENADE	71.2%
GRENADES; PEPPER, CS, ETC	65.4%
MID SIZE, RIOT CONTROL DISP	65.4%
STICKY SHOCKER	64.9%
GRENADES, SPONGE	64.6%
AQUEOUS FOAM	60.6%
OBSCRUANT (SMOKE)	58.8%
STUN GUN, ELECTRIC WIRE	56.7%
RC - CLOSE QUARTER	56.5%
STICKY FOAM	56.3%

VEHICLE PORTABLE	
TOTAL SCENARIO SCORES = 5150	
WEAPON TYPE	
WEASEL	71.1%
RCADD	66.4%
MCCM	66.0%
WATER CANNON	62.3%
LF SONIC ENERGY	56.4%
DIRECTED ENERGY	53.1%
STUN GUN, ELECTRIC FLUID	54.6%
ACOUSTIC JAMMING	46.9%

Figure 4. Inter-scenario commonality, emphasizing anti-personnel weapon suitability for multiple scenarios.

The matrix evaluation methodology also allows us to observe inter-scenario commonality to avoid single scenario sub-optimization. Figure 4 depicts the total weapons effectiveness scores in all six scenarios. The *italicized weapons* are those that were chosen in one or more of the individual scenarios. These weapons consistently received high weapons effectiveness score in all six scenarios. The mid size

riot control dispenser was a weapon that consistently scored high in most scenarios, but was also consistently outperformed by one of the other weapons.

Another benefit of the matrix analysis is its ability to point out deficiencies in the evaluated technologies. After two iterations of all current and proposed non-lethal technologies in the six scenarios, it became apparent that there existed a need for a system that could deliver these effects onto the target without exposing friendly forces to potential hostile fire. A notional remotely operated, armored vehicle was proposed by the Naval Postgraduate School (NPS) study group to fill this gap. Similarly a riot control agent directional dispenser (RCADD) was another in-house creation to fill another gap in current and proposed non-lethal technologies.

ANTI-VEHICLES								
WEAPONS TYPE	Eff. Range (>20 [redacted]	[redacted]	Time to Effect (ASAP)	Wep [redacted]	[redacted]	[redacted]	Weather Suscep.	Ranking
WF	[redacted]	[redacted]	4	[redacted]	[redacted]	[redacted]	5	100.0%
HP-MW MUNITIONS	**80**	**70**	36	**72**	50	63	45	75.4%
DEPOLYMERIZER	50	**80**	28	**64**	50	36	15	63.5%
POLYMERIZER	50	**80**	28	40	30	**72**	15	63.3%
DIRECTED RADIO FREQ	30	30	40	**64**	**70**	**81**	30	55.4%
DIRECTED MICROWAVE	10	10	40	64	**70**	**81**	30	50.6%
LASER	50	20	40	32	50	36	20	49.8%
DIRECTED EMP	10	10	40	**64**	40	**81**	40	45.9%
ROAD SENTRY	0	10	36	**72**	20	45	25	41.4%
VISCOSIFICATION	10	0	28	**72**	20	9	15	39.1%

Figure 5. Anti-Vehicles Preemptive Strike Scenario

The evaluation matrix can also show us if there are no feasible solutions to a particular scenario. The matrix in figure 5 is an evaluation of a non-lethal preemptive anti-vehicles strike. It may appear that the logical weapon suite should include the high-powered microwave munitions and a directed energy weapon. However, modeling this scenario with these weapons shows that the poor effective range and logistics requirements of a directed energy weapon renders this combination ineffective. Although the enemy can not easily counter the directed radio frequency weapon, our troops would have to maneuver a semi-truck sized weapon next to the target to be effective. This would certainly be unacceptable. Thus the matrix show us that the best we can do in this scenario is to a combination of the high power microwave munitions and a chemical attack to achieve most of the critical scenario requirements. Unless some new technology is developed we must accept the fact that the enemy may counter any weapon or combination of weapons used in this scenario. The evaluation can be a useful tool to focus research into areas where we are currently deficient.

In recent years the military has seen a tremendous number of proposed non-lethal technologies. Some of these promising technologies may comprise a tool kit capability that will expand mission situational dominance of the tactical officer in charge. The expanding utility of non-lethal weapons is critically dependent on the confidence gained through training and field employment. A system engineering analysis of the non-lethal tool kit will help differentiate the affordably promising and plausibly achievable from the science fiction. Furthermore, this outlined matrix approach can ascertain which weapon or weapon suite should provide the optimum solution, and if the same suite will be effective in various scenarios.

ABSTRACT: Non-Lethal Defense III Conference

Title:
Transitioning NLW Technology to the User

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Presentation:
The authors have been dealing with the implementation of DoD strategies to transition technologies into models, simulations, Advanced Warfighting Experiments (AWEs), and Advanced Concept Technology Demonstrators (ACTDs). In order to introduce and evaluate NLW technology in this context several issues need to be addressed. The authors will describe a methodology for incorporating existing and planned technologies as well as discuss some "hands -on" issues that need to be considered by program planners, material developers and the user community.

"OC Powder - The future of riot control"

The system concept which MP Laboratories, Inc. would like to represent, is a new chemical riot control agent. Currently, standard practice to control or disperse unruly crowds or demonstrators is to either launch or throw several pyrotechnic type tear gas grenades or projectiles. The pyrotechnic mixtures begin burning and release tremendous amounts of smoke, which contain the chemical agent. Today, tear gas grenades can be classified as either CS (o-chlorobenyzylmalononitrile) or CN (w-chloroacetophenone). The researchers at MP Laboratories, Inc. have developed a new riot control agent. It's effectiveness is such that pyrotechnic dispersion is not required but if desired this product can be adapted to this format also. The materials which comprise this product are generally considered "nonhazardous". The primary ingredient of this new riot control agent is Oleoresin Capisicum (OC). OC is extracted from hot peppers. Just as the aerosols containing "pepper" have taken control of the defensive spray market, OC in the riot control theater will become accepted quickly since it can be considered a "natural" chemical. Law enforcement agencies will rally behind the reduction of liability with this product. Pyrotechnic grenades have the ability to start fires, cause burns, and pollute the environment. CS and CN when used indoors tends to permeate porous materials which makes post operational cleanup very costly. OC will greatly reduce or eliminate these concerns and many others. All riot control agents have been known to cause injuries, and fatalities when used improperly. The use of this new OC dispersement powder does not reduce the need for adequate training for officers and troops having the possibility of being used for riot control. As with many other forms of training, training with OC must be done well in advance so that under the high pressure situation of an uprising, the proper and necessary steps to quell that riot are taken and mistakes are not made.

MP Laboratories, Inc. has developed an innovative process in manufacturing OC Powder by which coating inert and non-hazardous powders with OC. This new product is called OC Powder. This powder matrix has been developed to optimize safety, reduce the risk of fire hazard, encourage environmental friendliness, reduce potential health or death hazards over current technology, and situational adaptability in a variety of formats and devices for delivery where needed. OC powder is manufacturing controls include particle sizing, homogeneity, and flowability and cost.

OC powder is relatively new. OC powder is the next successive step in delivering a proven less than lethal lachrymatory agent into a wider more acceptable variety of delivery devices.

MP Laboratories, Inc. has moved this project past the concept and prototype phases of development and are currently marketing a variety of delivery methods for OC powder. The delivery technology involved has be around for over seventy years. The new innovation is to substitute the more highly volatile chemical agents with the safer product of OC powder.

Oleoresin Capsicum

Synonyms:

Capsaicin

N-[(4-Hydroxy-3-methoxyphenyl)methyl]-8-methyl-6-nonenamide

trans-8-methyl-N-vanillyl-6-nonenamide

N-(4-hydroxy-3-methoxybenzyl)-8-methyl-non-trans-6-enamide

OC

CAS Number: 8023-77-7 (Oleoresin Capsicum)

OC (Oleoresin Capsicum) is an extract of the cayenne pepper. Capsaicin is the active component of the oleoresin capsicum which is considered the "heat". In most cases, OC is dispersed by the use of aerosols but use of OC powders is growing and it is predicted to dominate the market in the coming years as the mainstay of riot control and crowd dispersement. OC aerosols, commonly known as pepper sprays, are readily available to consumers in many retail outlets and catalogues.

OC has a peppery odor. In low concentrations, the eyes will involuntarily close, have a burning sensation with profuse tearing. The nose will run, and exposed skin will have a burning sensation. OC is an inflammatory agent and will cause severe coughing, in concurrence with a tightness in the chest and throat. Occasionally, dizziness or swimming of the head will be experienced. All of the above effects are produced 60 seconds after dosing, and they will last for 45 minutes after being dosed. As with any riot control agent when used in the aerosol form there could be individuals which are either so motivated or influenced by drugs or alcohol that little effect will be produced. The inflammatory agent OC works very differently. OC causes gastrointestinal and dermal irritation along with bronchoconstriction. OC works directly on the nerves in the skin, eyes and lungs. OC seeks out the nerve structures of the eyes and causes involuntary closing of the lids. OC upon entering the lungs seeks out the pulmonary C-fiber neurons to cause rapid and shallow breathing. This sounds terrible but it is far less harsh than the active destruction of tissue which can be caused by its predecessors CS or CN. The decontamination of OC is much

easier and does not require extensive procedures for the cleanup of this biodegradable substance.

OC is less potentially lethal than CS or CN, but as with all chemical agents, these chemicals are "inherently dangerous" and should only be used at a level of force between "Control & Restraint" and "Temporary Incapacitation". OC has come under fire in recent times due to the inflammatory effects it has on the lungs and the devastating effects it has on asthmatics and other people with lung ailments.

And why not "OC"? It's environmentally friendly and it's much safer than the industry standards of CS or CN. CS and CN are both large synthesized organic chemicals. They will both cause incredibly disabling burns and cause extensive tissue destruction, if left on the individual for an extended period of time. They both cause gastrointestinal, dermal and pulmonary irritation but the safety margin of use is critical. These irritant agents work on the neural pathways to the brain. If these pathways are "numbed" by alcohol or drugs, most of their usefulness can be defeated and the irritants will be ineffective. CS and CN are very toxic and are recognized by the Department of Transportation as POISONS and CN is even considered a MARINE POLLUTANT. Decontamination and cleanup are also important issues which must be looked at. Both can be rather stubborn when trying to remove from a person or room in which it was used. Cleanup can take days to completely eradicate their presence.

Carriers, or chemical solvents and powders are another topic which must be looked at. At times, the solvent which carries the chemical agent can be just as or more toxic than the agent itself. This has to change. And it has, with this new formulation from MP Laboratories, Inc.

Products currently on the market include the dispersion by pyrotechnic means which include 37/38 mm projectiles, 35 and 66 mm grenades, and muzzle dispersive devices. Other means of dispersing the product include through pressurized aerosols, and compressed or forced air blowing devices. Chemical agents can be dispersed in three major ways, mechanical, chemical, and a combination of both. These dispersion methods can be broken down into a number of specific subcategories.

1. Mechanical Dissemination

A. Blast Dispersion of powders

Blast dispersion uses an explosive charge which upon ignition creates tremendous pressures which ruptures a weak point in the device allowing the chemical agent to be expelled with great force.

B. Nonblast dispersion of powders.

This generally entails the use of a high velocity air source which picks up the agent and carries it out of the device to disperse or the mechanical rupturing of a powder filled projectile.

2. Combined Chemical and Mechanical Dissemination

A. Aerosol streamers, mists, and foggers.

Commonly called defense sprays, this method is highly recognized and extensively used not only by the law enforcement industry but also by the consumer market. These devices use the mechanical force of pressured vessels to carry the solvent-carrying agent into the air.

B. Powder filled grenade

This type uses a small explosive force to activate a compressed gas which causes the grenade to expel it's powder.

OC Powder can be used in a variety of missions from riot and crowd control, barricade and hostage situations to its use in security devices. Using OC powder to quell large riots is very effective. It only remains in the area as long as needed. Clean up is simple as sending in street sweepers or flushing the streets with fire hoses. Because of it's environmentally friendly nature this agent may be flushed to storm drains.

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CAP-STUN
WEAPON SYSTEMS

ZARC® INTERNATIONAL, INC.

Innovation in Non-Lethal Weapon Technology

Non-Lethal Defense III
February 25 and 26, 1998

By: Cameron Logman

ZARC® is the founder of Oleoresin Capsicum (OC Pepper Agent) non-lethal weapon technology. This proprietary OC technology is currently packaged in an aerosol form under the recognized brandname **CAP-STUN®**, the very first pepper spray on the market developed for law enforcement and military application.

ZARC's client list includes more than three thousand state and local law enforcement agencies as well as the US Air Force, FBI, US Marshals Service, Drug Enforcement Administration, US Park Police, Secret Service and other US federal agencies.

This paper will provide an overview of the current existing CAP-STUN® products and also furnish a brief description of a technological leap being undertaken at ZARC®, in order to develop systems for use by modern military.

CAP-STUN®

CAP-STUN®'s technology is a unique compound and dispersion method currently in an aerosol form used by police and military to incapacitate unruly subject(s). CAP-STUN® is comprised of **Capsaicinoids** ingredients. *(Capsaicinoids are active ingredients within species of capsicum peppers (chili), which properly manipulated can become a potent medium to disable the target.)*

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Law enforcement and military have come to rely on CAP-STUN®'s unique advantages because CAP-STUN® provides:

- instantaneous control over violent or emotionally disturbed subjects,
- immediate impact on those under the influence of narcotics or alcohol,
- effective crowd control,
- the reduction of escalation to higher levels of force.

CAP-STUN®'s unique formulation and unmatched high performance record have been invaluable assets to law enforcement and military. Many incidents that previously would have led to violence have been prevented by the use of CAP-STUN® with a resulting decrease in injuries to subjects and officers and a reduction in civil litigation.

CAP-STUN® has a documented 95% effective rate, due to its unmatched Capsaicinoids content and dispersion technology. This is in drastic contrast to "civilian" pepper sprays with a 58% effective rate and numerous failures with documented injuries to subject and police officers.

CAP-STUN®'s EFFECTS

CAP-STUN® produces **inflammation of the mucous membranes** which lasts for up to 45 minutes with no after-effects. This immediate inflammation is the key difference between CAP-STUN's and other chemical agents and tear-gases. CAP-STUN® effects are:

- Immediate closing of the eyes.
- Coughing.

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CAP-STUN® IS SAFE

CAP-STUN® has undergone extensive independent toxicological testing. In over 10 years and tens of thousands of actual employment, there has not been a single substantiated instance of adverse reaction to CAP-STUN® by any subject, including those with respiratory illnesses, heart problems, poor reflexes or allergies.

CAP-STUN® in U.S. Department of Defense

ZARC® currently markets CAP-STUN® under various National Stock Numbers (examples: NSN 1365014073182 and 1365014076548).

The US military has used CAP-STUN® in several of its highly publicized peace-keeping missions including Rwanda and Guantanamo Bay. Military police from the U.S. Army 10th Mountain Division and 82nd Airborne Division as well as the U.S. Marine Corps 1st Marine Expeditionary Force have also used CAP-STUN® during operations in Haiti and Somalia.

In 1995, CAP-STUN® was adopted by military police units throughout DOD. The Air Force has made CAP-STUN® standard issue for its security police and Office of Special Investigations.

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The Navy utilizes CAP-STUN® for its Shore Patrol units in various Naval commands. Army and Marine military police units have been trained in the use of CAP-STUN® in several special sessions conducted at the Ft. MaClellan training facility. Primary US military police trainers, stationed throughout the world, participated in the training sessions conducted by ZARC®'s Director of Training. Additional military training sessions have been held at Miramar Naval Air Station, Travis Air Force Base, Andrews Air Force Base, and at the Defense Logistics Agency's training facility at Ft. Belvoir.

Non-Lethal vs. Less-Than-Lethal

ZARC® sees a clear difference between less-than-lethal and non-lethal weapons. Less-Than-Lethal Weapons are designed to minimize fatalities. There are various less-than-lethal weapons available. Projectiles such as rubber bullets, bean bags, sticky foam are categorized as less than lethal due to their high potential for serious injury and death. For example actual instances of fatalities caused by bean bags have been reported in Canada.

Non-Lethal-Weapons however, must be designed to incapacitate the subject, and properly used, should result in no injuries, fatalities or after effects.

ZARC® attempt is therefore to develop systems that are non-lethal in nature, bridging the gap that exist between police and military application of OC, and therefore satisfying the demands of the modern soldier, by utilizing their current platform of arms as well as providing new ones that are truly non-lethal.

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Technology Development

ZARC® is currently developing a more effective means of using CAP-STUN® in a non aerosol form.

All systems being developed by ZARC® are based on modified versions of ZARC®'s proprietary Capsaicinoids technology designed to be projected in a variety of devices in order to bring about temporary incapacitation without any adverse effects. Contact with these systems will cause rapid physiological reactions such as instant closing of the eyes and respiratory difficulty in targeted humans and animals. All technologies defined herein are in working concept and design development stage.

Types of Missions

Today's soldier must be equipped for peace-keeping and operations other than war, where civilians and non-combatants are present. The U.S. forces now will have to respond to a myriad of situations including urban warfare, across the range of military operations. At the same time, the military will face increased media attention, worldwide environmental concerns, and a low national tolerance for lethal and costly campaigns.

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Political, diplomatic, economic and humanitarian demands dictate that future operations, where possible, minimize U.S. casualties while limiting collateral civilian casualties. Global demand for non-lethal weapons is ever increasing because of:

- High cost of lethal force application.
- Peacekeeping operations.
- Humanitarian concerns.
- Pressures by human right organizations.
- Pressures by global media coverage.
- The need to minimize casualties.
- The need to minimize damage to properties.
- Operations other than war.
- Change of social consciousness to peaceful conflict resolution.

System Concepts

The systems that are being developed by ZARC® are designed for employment in the following Anti-Personnel applications:

- Close Proximity Encounters.
- Fleeing Suspects on foot.
- Hostage Situation.
- Crowd Control and Civil Disturbance.
- Barricaded subject and area/structure clearance.
- Non-compliant prisoner cell extraction.
- Animal and dog control.

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CAP-STUN WEAPON SYSTEMS

ZARC® will be developing three specific systems as follows. All systems are lightweight, portable and easy to use and maintain:

System 1 (***Close Proximity Device***): Pocket size, target precise, multiple shot, non-aerosol system, for indoor and outdoor application. Capsaicinoids projectile designed to be employed on one or several subjects at close distances of up to 33 feet (10 meters).

System 2 (**Medium Range Expulsion Projectile**): Capsaicinoids projectile standoff device, capable of covering a small or large area, projected up to 200 feet (60 meters) for immediate control and dispersal of crowds. Device will be effective against individual or crowds.

System 3 (***Long Range***): Capsaicinoids projectiles, designed to be launched from a variety of existing weapon platforms up to 600 feet (200 meters) without injuries to the subject or bystanders. This technology is designed to be projected to a human target, with an aim to subdue and control the subject without any injury. The projectile will be designed to be used in Large Riots, Hostage Situations, Fleeting suspect on foot, non-complying suspect and animal control, when the subject(s) must be controlled accurately from a distance.

The above systems will respond to the ever increasing demands for non-lethal force application for military use.

***Cameron Logman** is the President and CEO of ZARC®. Mr. Logman is recognized as the nation's foremost expert on Oleoresin Capsicum Weaponry and has written and lectured widely on the subjects. Publications authored by Mr. Logman continue to be some of the most significant writings on Oleoresin Capsicum Weaponry worldwide.*

A Brief History of Access Delay/Military Activated Dispensables and Their Potential for Usage as Non Lethal Weapons

Tommy D. Goolsby, Steven H. Scott
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ABSTRACT

Sandia National Laboratories (SNL) has been very active in physical security systems research and development for nuclear safeguards applications addressing both fixed-site and transportation security problems. Edgewood Research and Development Engineering Center (ERDEC) has been involved for many years in the development and application of smoke obscurants, irritants, and other materials uses for battlefield applications. Many of these material technologies developed over the past 20 years as part of the nuclear safeguards and military programs have potential utility for military and law enforcement non lethal weapons (NLW) situations. This paper will provide a brief history of several activated dispensables including their development, past applications and users, and potential applications for NLW scenarios. The activated dispensables to be discussed include: rigid foam, aqueous foam, countertraction materials, and sticky foam.

Rigid Foam Materials

Rigid foam systems are under current consideration for a wide variety of Non Lethal applications. A quick setting expandable rigid adhesive can be used for field expedient equipment disablement. Second, rigid foam systems can be used to assist in securing an urban environment. One of the many jobs of the Marines, Army infantry, and MP's (Military Police) is to clear an area such as a MOUT environment (urban buildings, residences, etc.) and then move on for further missions. Once U.S. troops have left the area, the enemy is free to move back into the cleared area reestablishing their foothold. But what if our troops can quickly, easily, and safely deny an area to the enemy and make it much more difficult for the enemy to re-take the cleared area after U.S. troops have moved on. A system proposed to do exactly this is the rigid foam system. Similarly, in access delay applications, rigid foams can be used to block passage ways, encapsulate protected items, and contain deployable barriers (entanglements) which provide further delay.

Modern consideration of military use of hardened adhesive pastes can be traced back to Nazi Germany employment of *Kaltklebekilt* equipment demolition kits, accomplishing demilitarization of abandoned ordnance through hand application of a tenacious adhesive cream. By the 1960's a robust US Army effort was underway to develop a number of specialized applications of structural foam constructions for military support of counterinsurgency and remote-area conflicts (Ref. 1). In the 1980's, rigid foams were employed for a number of experimental equipment defeating concepts under the ERDEC Antimateriel Munitions Program. Finally, a novel field expedient system for land mine neutralization using rigid foams was prototyped by the US Army Demining Technology Development group at Ft. Belvoir (Ref. 2).

A number of commercial developments are worthy of note also. During the 1960's, Seamans Delivery marketed a product called, "PREVENT-A-FOAM," used for riot control purposes, to block or channel roads and sidewalks. In the 1980's the Italian-made "Instant ARMY (Anti-Robbery Mass foam-Yielding system)" family of products were marketed for installation in high security vehicles. The system provided the capability to engulf transported valuables in rapidly expanding urethane adhesive foam when necessary. This system was at one time employed by vehicles employed by the French Post Office under the acronym STOP (*Securitisation du Transport des Objets Postaux*) (Ref. 3).

Polyurethane rigid foam systems have been proposed as a material which could be applied to doors, windows, sewer covers, and other entry ways found in the urban environment thus preventing reentry through those entry ways unless destroy or damaged. The effect would be three-fold. The attacker would leave a visual clue that reentry has taken place, the attacker would make a certain amount of noise trying to gain entrance, or the attacker would give up all together, looking elsewhere for easier entrance.

The rigid foam process is based on two major chemical components - polyol and isocyanate - which are precisely metered and mixed to form the foam composition. This reaction produces an exotherm (heat generated is used to vaporize a liquid "blowing agent" such as a fluorocarbon) and may be catalyzed, allowing extremely fast cure times. Other ingredients may be added in order to produce the specific type of foam or produce the particular properties for a specific application. These ingredients include water, auxiliary blowing agents, catalysts, fillers, colorants, and surfactants. One of the most important properties of polyurethane reaction mixtures is that they are powerful adhesives. The strength of any polyurethane system is directly proportional to the final cured density. As the density of the rigid foam increases so does its strength. However other properties change also, such as expansion ratio, viscosity of starting fluids, etc., which ultimately brings challenges for dispenser designers and in how the material is mixed and applied.

Investigations have been performed by ERDEC engineers in conjunction with engineers and scientists from Southwest Research Institute (SwRI) of San Antonio, Texas, in order to investigate the applicability of using commercially-available polyurethane spray foams for use as an entry denial material, as well as the possibility for use in construction of foxhole covers. Figure 1 depicts a US Marine utilizing polyurethane foam to seal and barricade an entranceway. The results obtained using commercial, off-the shelf materials were marginal. Typically, the commercial foams consist of 2-4 pound per cubic foot (pcf) density material, which produces an expansion ratio of 15 to 1. These multi-purpose foams are generally used in the building industry for insulation, fills, and seals in and around voids and irregular surfaces. SwRI has formulated a low density 2 pcf foam with a 30 to 1 expansion ratio which can produce a foxhole cover 4ft. in diameter, approximately 1.5 inches thick with sufficient strength to support an external load of 180-220 pounds. Also, a high density 8-10 pcf foam was formulated, with a low expansion ratio, in order to produce a high strength composition capable of sealing a door or window. Also, ERDEC/SwRI have investigated several epoxies and foaming epoxies which have incredibly high compressive, tensile, and flexural strengths (Ref. 4).

Research in this area is continuing at ERDEC into the area of polyurethane/epoxy hybrids, optimization of "classic" polyurethanes by addition of strength additives (ex: Kevlar), increasing reaction kinetics through catalyst chemistry, and composites. Data will be generated on cure times, temperatures at which reaction takes place and material strength.

Aqueous Foam

High expansion aqueous foam is an aggregation of bubbles that has the appearance of soap suds and is used to isolate individuals both visually and acoustically. Aqueous foam is formed when a water and foam concentrate solution is sprayed onto a perforated screen and a continuous movement of air passes through the screen. It can be used as a visual obscurant, fire suppressant, explosive blast suppressant, and irritant carrier. Aqueous foam properties such as collapse rate and stability can also be easily tailored to specific applications.

Aqueous foam was developed in the 1920's in England to fight coal mine fires and has been widely used since for fire fighting and dust suppression. It was first used in a military application during the Vietnam War, chiefly employing CS (ortho-chlorobenzalmalononitrile) laden foams in tunnel denial operations (Refs. 5,6). Concurrently during the 1960's, aqueous foams were also considered for civil unrest scenarios (Ref. 7). Based on this developmental experience, in 1975 ERDEC (then known as Edgewood Arsenal) was requested to study the use of this technology for nuclear safeguards and security applications (Ref. 8). Additional work at ERDEC for the Defense Nuclear Agency (DNA) during the early 1980's resulted in the development of a number of antipersonnel agent laced aqueous foam formulations, some of which were patented (Refs. 9,10).

Also in the 1980's, the Department of State had SNL designed aqueous foam systems installed in several embassies for use in riot situations (Ref. 11). SNL also has developed extremely stable aqueous foam formulations for use in Nuclear Emergency Search Team (NEST) applications. In late 1994, the National Institute of Justice (NIJ), the research arm of the Department of Justice, began a project with SNL to determine the applicability of high expansion aqueous foam for correctional applications (Ref. 12). Phase one of the project resulted in the selection of a non-toxic foam concentrate (foaming agent) with physical characteristics suited for use in a single cell or large prison disturbances. The selected foam concentrate was also shown to be an excellent carrier for Oleoresin Capsicum (OC) irritant (Ref. 13). An extensive toxicology review was also performed on the selected foam concentrate to verify its low toxicity. The selected foam concentrate was then used to conduct respiration simulation experiments which resulted in measured aspirates below the threshold level for aspiration pneumonia for a one hour immersion in the foam. A prototype cell extraction aqueous foam system, depicted in Figure 2, was also built and evaluated. The prototype system was used to do large scale foam physical characteristics testing of the selected foam concentrate, and was used for evaluation by correctional representatives. The NIJ aqueous foam project is discussed in greater detail in Reference 12.

In July 1996, SNL was requested by the U.S. Marine Corps (USMC) to participate in NLW Technology Evaluations held at Camp Pendleton. SNL provided USMC with the prototype hardware developed for NIJ, aqueous foam concentrate, toxicology and safety information, and training on use of the aqueous foam equipment (Ref. 14). The USMC evaluators conducted scenario testing with the aqueous foam equipment.

Based on military and correctional testing of aqueous foam, future NLW uses of aqueous foam could include crowd control, blocking choke points, protected area access delay and area denial. Issues that have hampered the application of aqueous foams for non-lethal use have been the integration of system hardware and logistical concerns of equipment size, weight, and water supplies (Ref. 15). Although supply water will continue to be an issue, integrated, self-contained trailer-based or palletized equipment platforms modified from fire fighting hardware can be

envisioned to allow rapid deployment and use in the field. Figure 3 depicts an SNL developed, application specific, integrated, self-contained, trailer-based aqueous foam platform. The depicted platform is aircraft transportable to provide rapid response and ease of deployment.

Countertraction Materials

The use of very low friction surface coatings has been suggested as a method of disabling vehicles or controlling crowd movement. In addition to roadways or sidewalks, similar targets such as aircraft runways or railroad tracks might also be targeted employing this technology. Furthermore, the application of a countertraction substance on hand operated equipment can prevent or hinder effective use due to a resultant inability to grip affected surfaces.

Modern military experimentation with this concept dates back to the US Army "Destabilizing Tactics" program, initiated during the Korean War (Ref. 16). During the 1956 Hungarian uprising against the Soviets, the insurgents were said to have been successful in hindering tank mobility by pouring oil on sloped streets to lessen traction. In attempting to hinder NVA (North Vietnamese Army) supply from the Ho Chi Min Trail in 1966-1967, slippery substances were evaluated for air delivery, to coat the roadways with water-activated materials. The US Army Tropic Test Center explored the concept in the late 1960's for riot control applications (Ref. 17). By 1981, the use of slippery material for intruder deterrence in weapons bunkers was successfully demonstrated by Edgewood Arsenal under the "Slippery Polymer Applications" program (Refs. 18,19).

Concurrent with this development, commercial ventures took root in the 1960's to employ this concept in riot control applications. The Western Company of North America marketed a product originally used to "make mud more slippery," facilitating the removal of drill bits from holes drilling for oil. Demonstrating this concept at a few of the annual National Police Equipment conventions of the mid-1960's, the product was dubbed "Riotrol." Dow Chemical marketed a similar chemical for riot control purposes called Separan AP-30. Other similar products marketed during this era were dubbed with more descriptive brand names - "Instant Banana Peel" and "Slippo." Other related commercial sector contributions include the production of artificial snow or ice surfaces to conduct winter sport activities, and applied tapes or sprays marketed as an alternative means of crawling insect control by denying them sure footing up a steeply inclined surface.

Some countertraction materials that have been considered in the implementation of this concept include specific types of polyacrylamides, carboxyvinyl polymers, or poly(ethylene oxides). Generally, these are supplied as dry white powders, and are activated by the addition of water. A second class of materials considered would include hydrocarbon-based lubricants, sometimes suggested with the addition of a dispersion of microfine fluorocarbon particles. Finally, the use of teflon or polyethylene confetti has been suggested, as the coefficient of friction of teflon on teflon is less than 0.1 (reduction of a friction coefficient much below 0.5 is generally considered to be a hazardous surface to walking personnel).

Past and current US Army countertraction technology programs have focused primarily on the water activated polymers such as the polyacrylamides. These materials should present little environmental or health hazards; many are even used in cosmetic or pharmaceutical products. As to ease of cleanup, the water-based materials have been shown to be removable through the use of high-pressure water jets. The ability of the resulting gels to sustain vertical stacking over surface smoothness imperfections is also a very important advantage in practical applications.

Effective concentration requirements for polyacrylamide based materials will vary depending on the smoothness of the surface to be treated. Studies conducted at US Army Land Warfare Laboratory recorded a requirement of 1 pound of material for 500 square feet of smooth concrete flooring (Refs. 18,19). Under the 1981 "Slippery Polymer Applications" program at Edgewood Arsenal, about 1 pound of powder was used to cover 100 square feet of rough macadam flooring (Ref. 20). Current ERDEC field trials conducted for the USMC joint NLW program have indicated that about 5 pounds of powder is required to successfully treat 100 square feet of roadway. In addition to the dry powder application, a quantity of water must also be provided to activate the material. Optimization of the weight ratio of powder to applied water is identified as an important parameter by the Edgewood project, generally taken to be about double the dry powder weight equivalent of water. Maximum effect is noticeably reduced at water applications far from the observed optimal ratio. Note that water/powder ratios are probably dependent on a number of external factors such as ambient temperature, average size of the dry polymeric particulate, degree of polymer crosslinking, etc.

These materials will not be applicable for universal usage. On paved non-porous surfaces, such as asphalt roadways or concrete runways, or on well-compacted soils these materials will produce very impressive results. However, on soft soils these materials have shown no useful effect. Heavy rain or high heat/humidity conditions will degrade the ability of this material to function effectively. One might diminish the effectiveness of this concept by simply covering the affected area with sand or dirt, or by wearing spiked shoes. Finally, for law enforcement use, the material will also adversely affect both emergency vehicles and personnel on the scene, until cleanup can be accomplished. An experiment conducted at ERDEC using a low coefficient of friction material resulted in the total immobilization of a truck as shown in Figure 4.

Sticky Foam

Sticky foam was developed at SNL in the late 1970's (Ref. 21) for use in nuclear safeguards and security applications. Sticky foam is a one-container, non-reactive foam which is stored under pressure and foams when released to atmospheric pressure. It is a very tacky and tenacious material that expands to over 30 times its stored volume when dispensed. It is comprised of rubbers, resins, oils, fire retardants and foam stabilizing chemicals. Many formulations of sticky foam have been developed for specific applications. Sticky foam also has high storage capability, contains a nonflammable solvent, is relatively volume-stable after dispensing, and requires effort and time to clean up. Sticky foam has an adherence tensile strength approximately an order of magnitude greater than common sticky materials such as molasses. Sticky foams can be deployed either passively, as in wall panel designs, or actively through nozzles, as with the sticky foam gun.

In late 1992, NIJ began a project with SNL to determine the applicability of sticky foam for law enforcement usage. The objectives of the project were to conduct an extensive toxicology and safety review of sticky foam (formulation SF-283), to develop a dispenser capable of firing sticky foam, to test the developed gun and sticky foam effectiveness on SNL volunteers acting out prison and law enforcement scenarios, and to have the gun and sticky foam further evaluated by correctional representatives. The results of the project are described in detail in Reference 22 but can be summarized as follows:

- Sticky foam is essentially non-toxic for the exposure conditions related to correctional and NLW applications.
- A capable shoulder-slung dispenser was developed and tested.

- Prison scenario effectiveness testing results were mixed: sticky foam exacerbates control and restraint problems for multiple inmates situations; however, some reduction in use of force was achieved for single inmate situations.
- Legal liability and potential suffocation concerns halted further development for prison or law enforcement applications.

In late 1994, SNL was contacted by USMC to provide non-lethal weapon support for Operation United Shield in Somalia. SNL provided USMC with several sticky foam guns, sticky foam, fill stations, emergency facial foam removal kits, training, and use protocol development. USMC performed extensive scenario testing, use-of-force protocol development, and toxicology/safety reviews prior to deployment in Somalia. Figure 5 shows USMC sticky foam gun training held at SNL. The results of the USMC sticky foam deployment are described in more detail in Reference 23, but are summarized below:

- USMC scenario testing reinforced potential applications for blocking of personnel and point access delay; however, the technology is not well suited for individual incapacitation or crowd control.
- The prototype sticky foam gun developed for correctional applications was ill-suited for military application due to limited sticky foam content, refill complexity, etc.
- Extensive reviews by both the USMC and U.S. Army (Ref. 15) have concluded that the material, deployment hardware, and safety limitations of sticky foams outweigh potential benefits. Sticky foams are no longer under consideration for further NLW research and development.

Acknowledgments
The SNL sticky foam, aqueous foam, and deployable barrier work was supported by the United States Department of Energy under Contract DE-AC04-96AL8500, the National Institute of Justice under Military Interdepartmental Purchase Requests 92-IJ-R-035 and 94-IJ-R-025, and a tasking by the Marine Corps 1st Marine Expeditionary Force Battalion. SNL is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

The current ERDEC Rigid Foam and Countertraction technologies work was supported by the Joint Non-Lethal Weapons Directorate, Quantico, VA.

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A Brief History of Access Delay/ Military Activated Dispensables and Their Potential For Use as Non-Lethal Weapons

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National Defense Industrial Association
Non-Lethal Defense III

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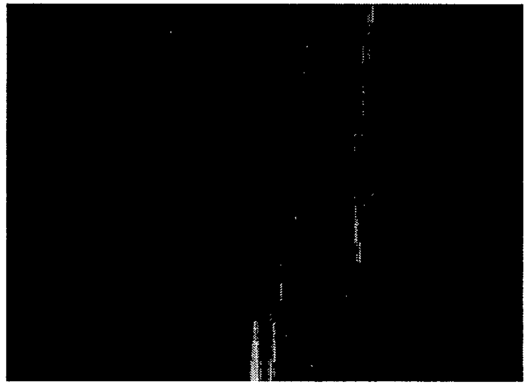
John Hopkins Applied Physics Laboratory

Access Delay and Military Materials Non-Lethal Applications

Sticky Foam



- Developed for access delay physical security applications - blocking, area denial, and target denial
- Characteristics
  - Exceptionally tacky/tenacious material
  - Good sustainability
  - Moderate expansion ratios (>30-to-1)
- One component, pressurized systems (100 - 225 psi)
- Extensive test & toxicology evaluation
- NIJ & USMC evaluations for non-lethal delay, blocking, personnel & equipment disablement
  - Deployed and utilized in Operation United Shield
  - No active development due to cleanup, personnel safety, operational logistics concerns

Access Delay and Military Materials Non-Lethal Applications

Photo of Sticky Foam Gun Testing

Photo of Airstrip Denial using Sticky Foam

Access Delay and Military Materials Non-Lethal Applications

Photo of Deployed Sticky Foam / Deployable Barriers

Department of State Aqueous Foam Application (1)

Department of State Aqueous Foam Application (2)

Access Delay and Military Materials Non-Lethal Applications

Wide Area Aqueous Foam Application

Access Delay and Military Materials Non-Lethal Applications

Integrated, Trailer-based Aqueous Foam System

Access Delay and Military Materials Non-Lethal Applications

Smart Material Development

Molecular engineering of polymeric materials / Microencapsulation

- Five potential degradation pathways
- Potential Applications
  - Reversible low-friction polymeric materials
  - Selective irritant release
  - Enhanced material strengths
  - Rate-sensitive shear thinning impact projectiles

Access Delay and Military Materials Non-Lethal Applications

Summary

- Sticky foams
  - One-component, extremely aggressive materials
  - Non-lethal issues with cleanup, operational logistics of pressurized deployment systems, personnel safety
- Aqueous Foams
  - Prior use in non-lethal delay / blocking applications
  - Potential broad applicability in non-lethal scenarios
  - Extensive support equipment required
- Countertraction
  - Limited prior uses; potential for roadway/runway denial
  - Issues of persistency
- Rigid Foam
  - Excellent for blocking, encapsulation applications
  - Significant commercial application formulation expertise

Access Delay and Military Materials Non-Lethal Applications

Future Plans

- Sticky Foams
  - No future non-lethal development planned
- Aqueous Foams
  - No current development
  - Future non-lethal applications require integrated deployment platform
- Countertraction
  - No current development
  - Chemical-based 'On/Off switch'
- Rigid Foam
  - Material optimization (all weather performance)
  - Packaging/Delivery issues

Countertraction Technology

- ***Objective:***
  - Use of very low friction materials to impede access to vehicles and personnel
- ***Materials:***
  - Hydrocarbon-based lubricant
  - Solid polymeric ‘confetti’
  - Water activated polymers

Rigid Foam

- ***Objective:***
  - Area denial, quick seal of doors and windows, and misc. antimateriel applications through application of quick-set rigid foams
- ***Materials:*** Polyurethanes, epoxies
  - Tenaciously adhesive/no surface preparation
  - Fast cure (seconds to minutes)
  - Expansive (5x to 50x)
  - Hardens to structural rigidity
- *Current project at ERDEC, SNL and SwRI*

DEFENSE AGAINST BIODEGRADATION OF MILITARY MATERIEL

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Non-lethal weapons represent novel threats to warfighters, requiring equally novel defensive measures. In addition to direct anti-personnel applications, such weapons may be designed specifically to degrade military forces' mobility, logistical support and equipment maintenance programs in a clandestine manner prior to or during military engagements, in a time frame of minutes to weeks. Such systems, patterned after microorganisms and their products, can be directed at non-living targets such as highway and runway surfaces, metal parts and coatings of weapons, support equipment and vehicles, fuels and other supplies and replacement parts. Microbial-derived systems may be used to accelerate the corrosion, degradation or decomposition of roads and aircraft runways. In addition, targeted deterioration of metal parts, coatings and lubricants of weapons, vehicles and support equipment, as well as fuels and other supplies, would significantly increase the cost and logistical burden of sustaining military operations. An important threat area addressed by this research includes denial of land areas to vehicles and aircraft by reduction of terrain trafficability and vehicle operation. Another very real threat involves the ability to disable or neutralize equipment and facilities, by degrading fuels and other supplies, and increasing maintenance requirements.

Nature has provided many examples of natural degradation by microorganisms of metals (1-4), fuels (5,6) and a variety of synthetic products (7,8), as well as structures and systems that incorporate or depend on such products. An example of a military material that such weapons may target is the synthetic high-strength polymer, Kevlar, or novel biomimetics of Kevlar based on spider silk. Asphalt is degraded by several strains of bacteria, leading to greatly reduced road surface lifetimes (9). Components of asphalt used for other construction purposes also suffer failure as a direct result of bacterial degradation (10). Cement is subject to rapid, component-specific attack by microbes (11). Most classes of paints and coatings are also vulnerable to degradation by microbial products (12-14). Virtually all petroleum, oil and lubricants (POL) of military relevance are vulnerable to degradation by microbial action (5). Many microorganisms also naturally produce minute granules called inclusion bodies that are made of salt crystals, metals or plastic-like compounds (polyhydroxyalkanates). These particles will quickly clog high efficiency filters, and convert critical lubricants of weapon systems into gums or abrasives. The initial phase of our research has focused on identifying and characterizing the degradative potential of products from naturally-occurring microorganisms. This work has been extended to the development of model microbial systems using genetically modified microorganisms (GEM) that express focused degradative capabilities. These will be further modified to be self-limiting, either by incorporation of timed "suicide" genes, or other alterations that prevent their persistence in the environment beyond pre-determined limits of space or time. The natural and model microbial systems are being studied to understand the enzymatic and other mechanisms by which

degradation of materials is effected. The knowledge of microbial degradation pathways gained in this study will be used to develop biomimetic chemical systems that reproduce the specific degradative capabilities, but without the requirement for living microorganisms. The genetic engineering techniques employed are standard laboratory practices, requiring no special isolation laboratories, and this materials science research is not restricted in any way by the 1972 Geneva Convention on Biological Warfare or any other international agreement.

The second phase of the research will focus on devising defensive measures, or "vaccination" strategies, to protect our military materiel against offensive actions that employ biodegrading microbes or their products. Extracellular enzymes from bacteria or fungi can easily be produced in large quantities, and potentially deployed for such purposes. For example, it is quite possible that microbial derived or based esterases might be used to strip signature-control coatings from aircraft, thus facilitating the detection and destruction of the aircraft. Countermeasures should be developed well in advance of need. One example of such "vaccination," involving the protection of polyurethane paints and coating, is described below. Naval ships and aircraft use polyurethane coatings in a variety of applications to protect surfaces from corrosion. Polyurethane is vulnerable to enzymatic degradation by a number of naturally occurring microorganisms (12,13,15,16). Current Navy aircraft coatings are two-component polyurethanes and are described in military specification MIL-PRF-85285C. The first component contains a polyol resin **A**, pigments, and other ingredients. The second component contains a polyisocyanate **B**. The curing reaction is shown in Scheme 1:

$$\underset{\textbf{(A)}}{R_1 - CH_2 - OH} \;+\; \underset{\textbf{(B)}}{R_2 - CH_2 - N = C = O} \;\rightarrow\; R_1 - CH_2 - O - \overset{\overset{O}{\|}}{C} - \underset{\underset{H}{|}}{N} - CH_2 - R_2$$

Scheme 1

To ensure rapid and complete reaction, and to keep the price of the starting materials comparatively low, primary isocyanates and primary alcohols are used as shown in Scheme 1. The sterically-unhindered urethane linkage thus produced is easily attacked and severed by esterases. Chemical groups that restrict or prohibit access of the enzyme to the urethane group confer stability against enzymic attack. Thus, the polyol of Scheme 1 could easily be modified as shown in Schemes 2 and 3 below:

$$R_1 - CH_2 - OH \;+\; HO - \overset{\overset{O}{\|}}{C} - \underset{\underset{CH_3}{|}}{CH} - OH \;\rightarrow\; R_1 - CH_2 - O - \overset{\overset{O}{\|}}{C} - \underset{\underset{CH_3}{|}}{CH} - OH \quad (+\,H_2O)$$

Scheme 2

$$R_1 - CH_2 - OH \; + \; \underset{\diagdown \; \diagup \atop O}{CH_2 - CH} - CH_3 \; \rightarrow \; R_1 - CH_2 - O - CH_2 - \underset{| \atop CH_3}{CH} - OH$$

Scheme 3

In Scheme 2, each primary hydroxyl group in the polyol is reacted with lactic acid to produce a terminal secondary alcohol. In Scheme 3, the polyol is modified with propylene oxide, which also creates secondary alcohol groups. Reaction of either of these modified polyols with isocyanate will produce a polyurethane coating essentially identical to that obtained from the unmodified polyol. However the coating will now contain blocked urethane groups that are "immune" to enzymatic attack.

There are some drawbacks to this approach. Secondary alcohols react slower than primary alcohols, so the curing time of the coating would be lengthened, or else the catalyst level would need to be raised. As a result, costs would also be increased.

Previous work at the Naval Research Laboratory (NRL) identified and produced in the laboratory an enzyme from a naturally occurring fungus, which rapidly decomposes polyurethane (15). This work was subsequently extended at NRL, to create a new genetically engineered microorganism that overproduces the polyurethane degrading enzyme (U.S. Patent, Navy Case No.75461) (16).

All of the armed services in a joint military operation will benefit from technology that protects the warfighters' overall ability to initiate and sustain combat operations. Vaccinating aircraft runway surfaces allows U.S. Air Forces to sustain operations to control the skies over enemy territory. Protecting road and highway surfaces supports the mobility of Army and Marine land forces, particularly troop and supply transport. Protecting fuels, replacement parts and other supplies that support a war effort gives an advantage to all branches of our military by enhancing logistical support systems. The potential for clandestine employment of these non-lethal weapon systems, particularly since their effects in many cases may closely mimic natural processes, gives an adversary the added advantage of deniability. For this reason, defensive measures must be proactive, rather than reactive.

In addition, characterization of degradative mechanisms and development of "vaccination" strategies will have significant dual use applications in protecting military and commercial materials and materiel from naturally-occurring biodegradation problems, as well as from offensive military and terrorist attacks of this nature. Scientific expertise capable of developing anti-materiel technology patterned after microbial systems unquestionably is already present in the laboratories of potential adversary states, and the likelihood of near-term development of such threats is great. Failure to counter this threat with a focused research program jeopardizes the warfighting capability of the U.S. and its allies.

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Examination of the Utility of Less-than-Lethal (LTL) Systems in an Exercise Simulated with the Joint Tactical Simulation (JTS)

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Executive Summary

The purpose of this project was to develop an initial method for studying the effects of less-than-lethal (LTL) systems on conflict, using the Joint Tactical Simulation (JTS) and to conduct a preliminary examination of the utility of LTL systems on the outcome of a specific scenario. The scenario examined was MegaGold, a Army exercise conducted without LTL weapons, with the goal of determining how the use of LTL systems in that exercise might have affected the engagement. The objective of MegaGold is for an Air Assault Battalion to clear a small village, containing both combatants and civilians, of enemy combatants.

Our initial model of the effects of LTL weapons, which was incorporated into JTS, defines a duration of personnel incapacitation as a function of which LTL weapon was used and range of target from the weapon. While incapacitated, an entity cannot move or shoot. In a confrontation where lethal force is to be avoided (such as against the civilians in MegaGold), LTL systems give Blue forces the flexibility to incapacitate without killing.

Red forces in the scenario include 21 troops, predominantly riflemen armed with AK-47s, but also including machine gunners and a sniper. Blue forces consist of three platoons of Marine infantry, together with another team. Blue troops numbered 124 in the scenario and included riflemen, grenadiers, semi-automatic weapon gunners, platoon leaders, and others. There were 50 civilians in the scenario, armed with rocks. Rocks thrown at Blue forces could incapacitate.

LTL systems used in the scenario included both ballistic systems (e.g., foam batons, bean bags) and chemical irritants (such as OC spray). The scenario was run four times without the LTL systems, and four times with them, and the results from the two sets of runs were compared, as shown in Table E-1. Although a total of eight runs is generally not enough to draw any statistically significant conclusions, time constraints prevented our doing more. Our hope was that these eight runs would bring some of the larger differences to light.

Examination of Table E-1 shows differences in numbers of Blue casualties, Red casualties, and Blue shots taken at civilians between the cases where LTL systems are and are not available. The difference in Blue casualties with and without LTL is significant at the 90% confidence level; the difference in Red casualties is significant at the same level. A greater number of runs might have shown a higher statistical significance; I estimate that approximately 20 runs would be needed for each case (with and without LTL) to make a stronger statement about the significance of these differences.

The difference in total number of shots fired by Blue is significant to beyond the 98% confidence level, as is the difference in number of lethal Blue shots fired at civilians. This result suggests that when Blue does not have LTL systems, Blue is at a loss for dealing with troublesome rock-throwing civilians. When LTL systems are available, Blue can engage the civilians—incapacitating them and getting them out of the way—with minimal danger of killing them.

Table E-1
Average values from running scenario MegaGold in JTS
with and without LTL systems

	Without LTL	With LTL
Blue casualties	33.3	21.5
Red casualties	11.8	15.3
Civilian casualties	1.5	0.8
Lethal Blue shots at civilians	21	2
LTL Blue shots at civilians	0	241

While this is a significant result, further work would allow us to explore many other fruitful areas. In MegaGold, for example, Red was greatly outnumbered by Blue. Furthermore, civilians in this exercise were not generally enough of a problem to Blue forces to warrant use of lethal force against them—if they had been, we would expect to find that civilian deaths decrease when LTL systems are made available to Blue. Some of the questions we would like to answer are:

—what happens when Red and Blue are more evenly matched?

—what happens in a scenario where civilians are more of a problem to Blue forces?

—which LTL weapons are most effective, either alone, or as part of a weapons mix?

—which LTL systems allow Blue to accomplish his objective in minimal time, with minimal civilian deaths?

MegaGold was not designed to answer these questions—it was a scenario of opportunity. It is to be hoped that further work will provide us the opportunity and resources to be able to study scenarios specifically designed to study the issues of most interest to the LTL community.

Introduction

The purpose of this project was to incorporate algorithms describing the behavior of less-than-lethal (LTL) systems into a version of the Joint Tactical Simulation (JTS), a high-resolution, entity level, force-on-force battle simulation, and to conduct a preliminary examination of the utility of LTL systems on the outcome of a specific scenario. Consistent with the requirements of the Commandant's Warfighting Lab, the scenario examined was MegaGold, an Army exercise conducted at Ft. Campbell which was to have involved LTL systems. Because permission to use LTL munitions in the exercise was withdrawn, actual LTL use in MegaGold was not examined. This simulation analysis of MegaGold is therefore the only study of the use of LTLs related to that exercise.

Modification of JTS to include LTL effects

It was decided that duration of personnel incapacitation as a function of weapon and range from weapon would constitute our initial model of LTL systems. While incapacitated, an entity is unable to move or to shoot. Two kinds of weapons are defined in the code: point effect weapons (such as rubber bullets), for which the relevant range is how far the target is from the shooting system, and area effect weapons, such as UAV-deployed pepper spray or whistlers, where the relevant parameter is distance of the victim from where the system was deployed, independent of where it was shot from. Data for a particular LTL system are entered as triplets of range (in meters), incapacitation time (in seconds), and standard deviation of incapacitation time (in seconds).

In addition to these agreed upon changes, the code was also modified to allow a LTL weapon to deplete its target's energy supply. (The JTS model allows assignment of an energy level to each entity, and energy is expended each time the entity does something.) This data also is entered in triplets of range (meters), energy depletion (cal), and standard deviation (cal). The energy depletion feature was not used in exercise MegaGold. A detailed description of how to use the model is included in Appendix A.

Simulation of Exercise MegaGold

In MegaGold, the objective is for an Air Assault Battalion to clear a small village, containing both combatants and civilians, of enemy combatants. Because local goodwill is desired, civilian casualties are undesirable. LTL

systems for the scenario included both ballistic systems and irritants, which are direct fire, point effect weapons.

Figure 1 shows a diagram of the village used for the exercise. Appendix B provides both a detailed description of Marine actions in the village and a set of diagrams illustrating the planned mission, which was to secure the village. This was accomplished by Marine units moving from building to building.

Red forces in the scenario include 21 troops, 7 regulars training 14 militiamen. Red units are predominantly riflemen armed with AK-47s, but also include machine gunners and a sniper.

Blue forces consist of three platoons of Marine infantry, called first, second, and third platoons in the scenario (Appendix B), together with another team called Team Wardog. The three platoons contained trucks and helicopters; Team Wardog had UAVs. Excluding vehicles, Blue troops numbered 124 in the scenario and included riflemen, grenadiers, semi-automatic weapon (SAW) gunners, platoon leaders, medics, and others. In the non-lethal runs of the scenario, Blue units carried not only their lethal munitions, but also non-lethal munitions which could be used with the same weaponry. Because Blue was not to engage civilians lethally unless absolutely necessary, it was decided that Blue would not shoot lethal systems at civilians unless the civilians were within 5 meters of the Blue unit.

There were 50 civilians in the scenario. Civilians were armed with rocks. Rocks were modeled as LTL systems with a maximum range of 50 feet and the ability to incapacitate for an average of 49 seconds. (See Appendix C for the data on LTL systems.)

Process

Eight runs of JTS were made, four without LTL systems and four including them, with Marine lieutenants interactively playing Red and Blue. A civilian contractor played the civilian forces. Each scenario took approximately two hours of game time to run. Because of computer system problems, some of the eight runs were not completed. Table 1 shows game time for each of the runs. A complete run took 110 to 120 minutes; those runs which are shorter than that were not completed due to computer problems.

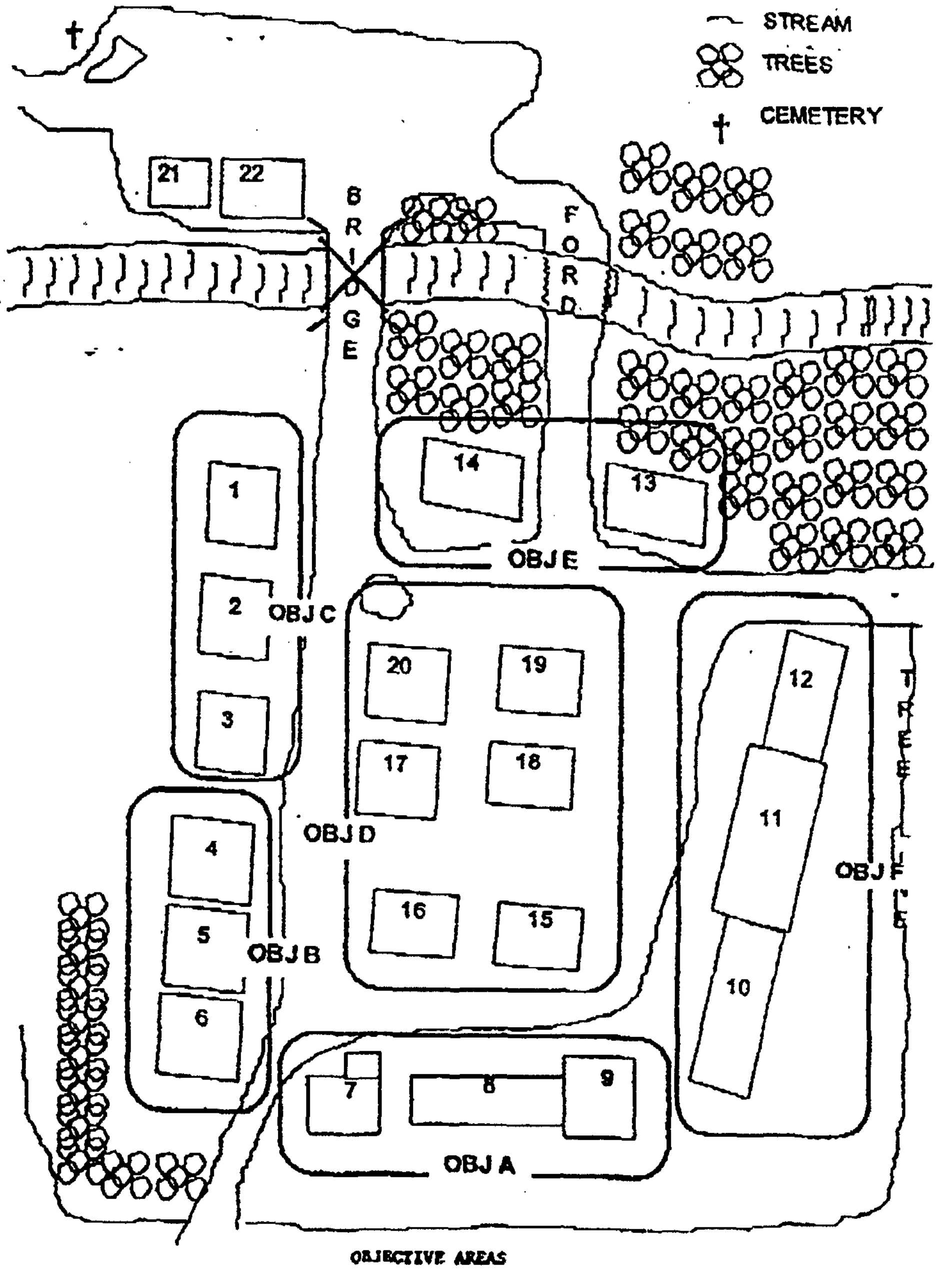

Figure 1. Diagram of the village used in exercise MegaGold, showing the Marines' objective areas. Further details can be found in Appendix B.

Table 1
Run times for the scenarios

Scenario number	Run time (minutes)
16a	110.32
16p	83.70
17a	115.70
17p	120.19
18a (LTL)	38.27
18p (LTL)	57.21
19a (LTL)	113.54
19p (LTL)	113.60

The scenarios are labeled according to when they were run: scenario 16a, for example, was run on the morning of the 16 December, 1996. The table clearly indicates that scenarios 16p, 18a, 18p were unable to finish. In all runs where the scenario was completed, the Blue mission was accomplished.

Appendix C lists the LTL equipment carried by Blue units and the data used to describe the LTL systems. This data was collected from police departments by the Naval Surface Warfare Center. It is noteworthy that none of the systems is, according to the data, effective at ranges greater than 15.2 m, and that all the point effect systems have incapacitation times under 80 seconds, although some of the area effect systems can incapacitate up to an hour.

Results

Table 2 presents casualties for each run. Red and civilian casualties are due to Blue fire; Blue casualties are due to Red fire.

Table 2
Casualties for each run

	Casualties		
Scenario number	Blue	Red	Civilian
16a	13	11	1
16p	45	12	1
17a	50	12	1
17p	25	12	3
18a (LTL)	5	10	0
18p (LTL)	16	9	0
19a (LTL)	37	21	0
19p (LTL)	28	21	3
Avg (St Dev) no LTL	33.25 (17.3)	11.75 (0.5)	1.5 (1.0)
Avg (St Dev) with LTL	21.5 (14.0)	15.25 (6.7)	0.75 (1.5)

Notice that scenarios 18a and 18p show fewer casualties than the others. This is attributable to computer problems which did not allow the scenarios to finish. Although scenario 16p did not finish, Red made an early attack on Blue's 1st platoon early in the game, explaining the high Blue casualties.

Because of the way this scenario was played, and particularly because the civilians were not, for the most part, greatly irritating to Blue, few civilians were killed in both the lethal and LTL cases.

Although it is interesting that availability of LTL weapons to Blue appears to have resulted in fewer Blue casualties and more Red casualties, these casualty differences are statistically significant only to the 90% confidence level. More runs of the scenarios might have allowed stronger conclusions about the significance of these differences. I estimate that approximately 20 runs each of the scenarios with and without LTL weapons might show significance at the 95% level. (Statistical significance at the X% level means that only 100-X% of the time will the conclusion that the two things are different be in error, because the appearance of difference is due only to chance.

Differences in civilian casualties are not statistically significant. (A lack of statistical significance means that the data do not support the conclusion that civilian casualties are different with and without LTL systems at any "high" (say, more than 70%) confidence level.) In order to see a significant difference in civilian casualties, we would need to examine a scenario where civilians

were more of a problem to Blue, so that Blue would be engaging them even without LTL weapons (i.e., killing them).

Table 3 presents engagements of Blue forces on civilians for each scenario.

Table 3
Blue shots at civilians

Scenario number	Number of shots
16a	15
16p	4
17a	4
17p	62
18a (LTL)	114
18p (LTL)	144
19a (LTL)	346
19p (LTL)	368
Avg (St Dev) no LTL	21 (27.7)
Avg (St Dev) with LTL	243 (132.5)

On average, Blue engagements of civilians increased by an order of magnitude when LTL weapons were available to Blue forces. Without knowing anything about the distributions of Blue engagements and using rank information only (which gives a conservative estimate of the statistical significance of this difference), the difference is significant at the 98% confidence level.

Table 4 lists the LTL munitions used in the scenario and presents the average number of LTL shots fired (and how many civilians were incapacitated by them) for each LTL munition.

Table 4
Number of LTL munitions shot at civilians
(Averaged over the four LTL runs)

Munition	Average number fired	Average no. incapacitations	Incapacitations per shot
DT23BR 12G Bean Bag	46	15	0.326
DT23FS 12G Fin Stab.	102	37	0.363
DT40A Stinger	23	11	0.478
DT40B Stinger	12	5	0.417
DT40F Foam Baton	9	1	0.111
DT40W Wood Baton	32	14	0.438
MK4 OC Spray	15	9	0.600
MK9 OC Spray	2	1	0.500
Stinger Grenade 15*	7	3	
Total direct fire*	241	93	0.386

*The stinger grenade is considered an indirect fire system and is capable of incapacitating more than one target per round. Stinger Grenade shots are not included in this total.

Although it appears that the Mk4 and Mk 9 OC Spray may be more effective than the other LTLs, and that the DT40F Foam Baton may be less effective than the others, statistical tests do not support such conclusions: more data is necessary before we can reliably determine which LTL systems are more effective than others in the simulation. Such data would include more (at least 30) shots of each weapon. It would also be useful to put each weapon, individually, in a certain role and compare the results for various weapons to learn which weapon best suits which military role.

The data provided by the current version of JTS includes a record describing an entity's incapacitation and what it is due to, but it does not include how long the entity is incapacitated. Although most of the LTL systems incapacitate for similar lengths of time (31 to 76 sec), the OC Sprays incapacitate for 15 minutes to an hour and thus could be deemed more effective for that reason.

Subtracting the average LTL firings (241) from the average number of shots fired by Blue on civilians (243, from Table 3) reveals that Blue fired an average of two lethal shots when LTL weapons were available, approximately

one-tenth as many as when LTL weapons were not available (21, from Table 3). The finding here is that when LTL weapons are available, Blue shoots lethal weapons only rarely: 99% of Blue shots at civilians are LTL.

Table 5 shows the number of rocks civilians hurled at Blue forces in each scenario.

Table 5
Number of rocks thrown by civilians at Blue forces

Scenario number	Number of rocks
16a	48
16p	24
17a	64
17p	95
18a (LTL)	12
18p (LTL)	5
19a (LTL)	57
19p (LTL)	82
Avg (StDev) no LTL	58 (29.8)
Avg (St Dev) with LTL	39 (36.8)

The apparent drop in the number of rocks thrown when Blue forces had access to LTL systems is probably an artifact of scenarios 18a and 18p ending before the part of the scenario where most of the rocks are thrown. The difference in number of rocks thrown in the scenarios with and without LTL weapons is not statistically significant, even taking into account that scenarios 18a and 18p ended early. None of the rocks had any effect in killing or suppressing Blue units.

Conclusions

Examining the numbers in the tables above leads to the discovery that the availability of LTL systems allows Blue to engage civilians in arenas where Blue would otherwise be unable to act. That the number of direct fire

engagements against civilians increases by a factor of 12 when LTL systems are available indicates that LTL systems give Blue forces the flexibility to deal with civilian distractions in cases where the distraction is not sufficient to warrant lethal force.

Although Table 2 indicates that Blue losses decrease when LTL systems are present (from an average of 33 to 21), this may be a consequence of the early termination of some of the LTL scenarios and is statistically significant only at the 90% level. The finding that Red losses increase (from an average of 12 to 15) when LTL weapons are present is significant at the same level. A greater number of runs might have shown a higher statistical significance; I estimate that approximately 20 runs would be needed for each case (with and without LTL) to make a stronger statement about the significance of these differences.

Because the civilians in this exercise were not generally enough of a problem to Blue forces to warrant lethal force against them, the difference in number of civilian deaths as a function of availability of LTLs is inconsequential. If we had studied a scenario where civilians posed more of a problem to Blue, it is to be anticipated that the introduction of LTLs might have allowed Blue to deal with troublesome civilians in a non-lethal manner, sparing civilian lives relative to the case where Blue is limited to a choice of using or not using only lethal weapons. This is likely to be a fruitful area for later studies.

The scenario chosen for this exercise was one where Blue accomplishes its mission handily both with and without LTL weapons. A scenario where Blue and Red forces are more evenly balanced, and where the successful accomplishment of Blue's objective is not certain, might more readily show differences in mission accomplishment or civilian casualties between the cases where LTL systems are available or not. Further work could productively explore the extent to which having LTL weapons makes a difference in casualties on each side when Red and Blue are more evenly balanced.

A study such as this raises many questions, such as:

— which LTL systems are most effective both individually and as components of various weapons mixes?

—does the availability of LTL systems result in fewer Blue or civilian casualties?

—Can the military objective be accomplished more quickly with certain LTL systems or mixes?

This is hardly an exhaustive list. Such an analysis could be done by varying the LTL systems available to the Blue force and examining the results.

For this analysis, we were given an exercise (MegaGold) and asked to study the effects of including LTL systems. A more productive piece of work, from the standpoint of being able to answer specific questions about the effects of LTL systems, would begin with a scenario tailored to the study of those systems and would allow sufficient time to do many JTS runs. With such a scenario and a few weeks for running the simulation, we expect that we would be able to address many of the issues raised in this report.

Acknowledgements

This work would not have been possible without the excellent and professional support provided by the very knowledgeable JTS team (headed by Mr. Joe Flores and Maj. John Kelly) at Quantico, who actually did the runs and provided us with their results.

LEGAL AND ETHICAL GUIDING PRINCIPLES AND CONSTRAINTS CONCERNING NON-LETHAL WEAPONS TECHNOLOGY AND EMPLOYMENT

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Development and employment of non-lethal weapons and their associated technologies require legal and ethical review prior to the procurement and acquisition process. Non-lethal technologies apply to the entire spectrum of conflict in the post Cold-War environments, including Military Operations Other Than War. However, the use of these non-traditional methods must still adhere to the same principles which have historically guided the conduct of our armed forces, namely, humanitarian law, customary international law, and the Law of Armed Conflict.The unconventional technologies associated with non-lethal weapons make them sensitive to the provisions of more recent treaties and conventions, including the Chemical and Biological Weapons Conventions and the four Protocols of the Certain Conventional Weapons Convention and the appended 1995 Supplement. In addition, other treaties such as the Nairobi International Telecommunications Convention and the Montreal Protocol on the Substances that Deplete the Ozone Layer may impact the use of certain non-lethal weapons technologies.

The three major issues of the Law of Armed Conflict apply to non-lethal weapons: proportionality of inflicted suffering balanced against military necessity; discrimination in effect; and extant rules of law. Domestic laws including those that regulate environmental and occupational health considerations also affect non-lethal weapons and their use. In this discussion, we shall present aspects of history and DoD directives and interpretations with the intention of engaging in dialogue involving legal and ethical considerations provoked by the technology of non-lethal weapons.

Although some NLWs have been deployed, the acquisition process has proceeded slowly. DOD Instruction 5500.15, "Review of Weapons under International Law," requires that any new weapon undergo a legal review by the Judge Advocate General (JAG) of the appropriate military department to ensure that its intended use is consistent with the "obligations assumed by the United States Government under all applicable treaties, with customary international law, and, in particular, with the laws of war."[1] Acquisition and procurement of weapons must be consistent with all applicable treaties including arms control agreements and customary international law. The responsibility for compliance resides in each Service Component and the Under Secretary of Defense for Acquisition and Technology (USD, A&T), in coordination with the Office of the Secretary of Defense (OSD) General Counsel and the Under Secretary of Defense (Policy). The legal review must take place before the award of the engineering and manufacturing development contract and before the award of the initial production contract."[2] The Department of the Navy JAG has functional responsibility to conduct the legal review of NLWs under SECNAVINST 5711.8A, "Review of Weapons under International Law,"[3] and SECNAVINST 5000.2B, "Implementation of Defense Acquisition Management Policies, Procedures, Documentation and Reports."[4]

The Navy JAG has completed legal reviews of the Stinger Grenades; 12 gauge shotgun bean bag/ rubber pellets/ wood baton rounds; 40 mm rubber pellet/, Foam Rubber Multiple Baton/ Bean Bag/ Wood Multiple Baton Rounds; sticky/restraining foam; barrier foam; 40 mm practice M781 round modified

[1] Department of Defense Instruction 5500.15, Subject: Review of Legality of Weapons Under International Law, October 16, 1974.
[2] Department of Defense Directive 5000.1, Subject: "Defense Acquisition." March 15, 1996, p. 7.
[3] SECNAVINST 5711.8A, "Review of Weapons Under International Law."
[4] SECNAVINST 5000.2B, "Implementation of Defense Acquisition Management Policies, Procedures, Documentation and Reports."

with foam rubber projectile.[5] Other NLW are currently being considered as the review process is not static. Additionally, The International and Operational Law Division of the Deputy Assistant Judge Advocate General has recently completed its legal review and approval of proposed new, advanced or emerging technologies which may lead to development of weapons or weapons systems that are under consideration by the the Joint DoD Nonlethal Weapons Program.

Anti-personnel technologies including gastrointestinal convulsives, calmative agents, sticky foam, aqueous foam, adhesives, malodorous agents, oleoresin Capsicum (OC) Cayenne Pepper Spray, smokes and fogs, riot control agents (CS & CN), slick coatings/superlubricants and anti-material technologies such as viscosity/surface polymerization agents, corrosive and supercorrosive agents, caustic agents, embrittling agents, depolymerization agents, combustion modifiers, sticky foam, adhesives, microbes, and slick coatings/superlubricants are candidates for acceptance in the military inventory. Microbes represent the only legally reviewed technology that did not receive approval for development since this category of weapon violates the Biological Weapons Convention.[6] Calmative and gastrointestinal convulsives, if classified as RCAs, can be acceptable within the context of the BWC. Once these technologies evolve into actual weapons and weapons sytems, Navy JAG will then review and analyze them in light of their toxic properties and compliance with all extant international laws and treaties and domestic restrictions before granting final approval or rejection.

Although the research and development of nonlethal weapons technology, doctrine, and training are still in the embryonic stage, their potential for future options to commanders should not be underestimated. The new evolving "homeland defense" military strategy proposed by the National Defense Panel underscores the importance of nonlethal weapons doctrine and training in domestic support operations and environments that preclude the use of deadly force, such as humanitarian assistance, peacekeeping, emergency operations and other MOOTW.[7]

In conducting its legal weapons review, the Navy JAG analyzed certain International Agreements that had direct relevance to the military use of NLWs and addressed three major issues pertaining to the Law of Armed Conflict: 1) does the weapon cause suffering that is needless, superfluous, or disproportionate to the military advantage reasonably expected from the use of the weapon? 2) can the weapon be controlled so as to be directed against a lawful target and be discriminate in its effect? and 3) are there any extant rules of law that prohibit its use in the law of armed conflict?

These major issues form the Law of Armed Conflict concept of proportionality that all weapons and military action can cause suffering, but stipulates that any suffering caused must be balanced against military necessity. Proportionality is subsumed within the overarching concept of humanity which requires that combatants and non-combatants not be subjected to unnecessary suffering. From these basic concepts derive the principles governing the prohibition and control of certain weapons: unnecessary suffering principle, the discrimination principle and the treachery or perfidy principle.[8] Legal and ethical precedents having historical roots established a framework within which current military legal counsels can consider non-lethal weapons and their applications to the entire spectrum of conflict.

Present and future non-lethal weapons

[5] Judge Advocate General, Department of the Navy, Subjects: "Legal Review of Stinger Grenades, Jan 25, 1995, "Legal Review of 12 Gauge Shotgun Bean Bag/Rubber Pellet/Wood Baton Rounds," Jan 30, 1995, "Legal Review of 40mm Rubber Pellet/Foam Rubber Multiple Baton/Bean Bag/Wood Multiple Baton Rounds," Jan 30, 1995, "Legal Review of Sticky/Restraining Foam," Feb 6, 1995, "Legal Review of Barrier Foam," Feb 6, 1995, "Legal Review of 40MM Practice M781 Round Modified With Foam Rubber Projectile," Feb 7, 1995, Deputy Assistant Judge Advocate General, International and Operational Law, Navy JAG, 2000 Navy Pentagon, Washington, D.C. 20350-2000.

[6] "Legal Review of Proposed Chemical Based Nonlethal Weapons," Deputy Assistant Judge Advocate General, International and Operational Law, Navy JAG, the Pentagon, Washington, D.C. Proposal of March 10, 1997 and final review and approval documentation, signed November 30, 1997. Telephone interviews conducted with Navy JAG, September 30, 1997 and December 5, 1997.

[7] Bradley Graham, "Experts Urge Upgraded Defense of U.S. Territory - Congressionally Chartered Panel Takes Issue With Pentagon's Two-War Scenario," The Washington Post, December 2, 1997, p. A15

[8] Ibid.

such as lasers, directed energy weapons, high-power microwaves and infrasound, weapons developed from biotechnology and genetic engineering, and chemical and biological weapons must be analyzed according to these established laws and principles. The ground work for the declarations and conventions that pertain to legal review of NLWs was already well established in the Lieber Code of 1863 and the Declaration of St. Petersburg of 1868.

The Lieber Code, the cornerstone of humanitarian law, established that military necessity does not include means and methods of warfare that are cruel, and that military necessity does take into account the long-term consequences of the use of a particular weapon.[9] A few years later, as a result of a general feeling of abhorrence for certain inhumane weapons, the Declaration of St. Petersburg was signed. It prohibited the use of certain weapons that "uselessly aggravate the sufferings of disabled men, or render their death inevitable."[10] These historical documents, along with the Hague Declarations (1899) Concerning Asphyxiating Gases and Concerning Expanding Bullets, and the Hague Convention (1907), Respecting the Laws and Customs of War on Land, and the concomitant protocols, provided the historical basis for the development of future conventions and treaties.[11]

The use of foam provides an example of the analysis done by the Navy JAG prior to the acquisition and procurement process.[12]

The Chemical Weapons Convention (CWC) was signed on January 13, 1993 by the US and ratified in 1997. The CWC definition of toxic chemicals does not apply to Sticky Foam which acts as a "high-tech lasso" restricting the movement of an individual's limbs. It does not rely on any toxic properties to disrupt human life processes and it is essentially non-toxic. Sticky Foam is not considered a riot control agent (RCA) which is a chemical prohibited as a method of warfare only when its toxic properties are intended as the primary means of inflicting temporary disability. It is Sticky Foam's binding property, not its toxicity, that is its primary disabling mechanism. This characteristic clearly distinguishes it from CS and CN gas, both of which depend on their chemical effects on the human body for their riot control efficacy. It should be noted that since the expression, a "method of warfare" is not defined in the CWC treaty, RCAs may be used during all other operations not involving international armed conflict such as operations in peacekeeping, humanitarian or disaster relief, noncombatant evacuation, counterterrorist operations such as hostage rescue, and law enforcement.

During the legal review process, Sticky Foam raised an international environmental law issue related to the Montreal Protocol on Substances that Deplete the Ozone Layer. Dichlorodifluoromethane or Freon-12 is an ingredient comprising 30-32% of Sticky Foam. Placed on the list of controlled substances, Freon-12 was phased out on an accelerated basis. The Clean Air Act, which implements the Montreal Protocol, and the EPA banned production and consumption of all Freon-12 after December 31, 1995.[13]

Under the CWC, Barrier Foam, classified as a RCA, may not be used against combatants in armed conflict.[14] The restriction on the use of barrier foam resulting from the President'a June 1994 memo interpreted the phrase "method of warfare" as applicable to the conjunction of both a circumstance (international or internal armed conflict) and a class of targets (combatants, including where combatants and

[9] Human Rights Watch Arms Project (1995b), "Blinding Laser Weapons: The Need to Ban a Cruel and Inhumane Weapon", Human Rights Watch, Washington, D.C., September.

[10] W. Michael Reisman and Chris T. Antoniou, eds. The Laws of War: A Comphrehensive Collection of Primary Documents on International Laws Governing Armed Conflict, Vintage Books, New York, July 1994, p. 35.

[11] Ibid., pp. 38-150.

[12] Judge Advocate General, Department of the Navy, ibid.

[13] Judge Advocate General, Department of the Navy, Subject: "Legal Review of Sticky/Restraining Foam," Feb 6, 1995, pp. 1-6.

[14] RCA use was unacceptable in armed conflict because it could easily be confused with chemical weapons of a more lethal nature by the enemy who could then be provoked into escalating the conflict via a retaliatory response. In Vietnam, RCAs were used for offensive purposes and as a result received widespread public disapproval. Soldiers employed RCAs first to "smoke out" the enemy hiding in tunnels or other obscure locations. Once the enemy was out in the open, the American soldiers then fatally shot them (rather than taking them as prisoners of war). Consequently, the use of RCAs against combatants in armed conflict has been legally disallowed. Interview with Navy JAG, October 30, 1997.

noncombatants are intermingled). Since Barrier Foam contains CS, a RCA, under the CWC it may not be used against combatants in armed conflict.[15]

The Biological Weapons Convention signed by the US on April 10, 1972 and ratified in 1975, bans the development, production, stockpiling or acquisition of biological agents or toxins of "types and quantities that have no justification for prophylactic, protective, or other peaceful purposes."[16]

The 1986 Nairobi International Telecommunications Convention restricts the use of electromagnetic weapons. Article 35 (1) prohibits "harmful interference" with the radio services or communications of Member states. The US, which is not a party to this treaty, has nonetheless implemented its provisions by incorporating them into US law (47 US Code 502). Treaty provisions do not apply during wartime. Although "wartime" is not defined in the treaty, it would certainly apply to MRC but their status in MOOTW operations is not unambiguous.

The 1977 Environmental Modification Convention (Convention on the Prohibition of Military or Other Hostile Use of Environmental Modification Techniques - "ENMOD") is the treaty that regulates the use of environmental modification as a weapon of war. It defines environmental modification techniques as "changing through deliberate manipulation of natural processes the dynamics, composition, or structure of the earth, including its biota, lithosphere, hydrosphere, and atmosphere, or of outer space." ENMOD prohibits techniques having widespread (several hundred square kilometers), long-lasting (months), or severe (serious or significant disruption or harm to human life, natural and economic resources, or other assets) environmental effects as the means of destruction, damage, or injury to any other State Party. Given these restrictions, the US will not develop NLWs that violate any of these criteria.[17]

The Geneva Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous, or Other Gases, and of Bacteriological Methods of Warfare of June 17, 1925 entered into force 8 February 1928. There are several legal issues of concern regarding the use of chemical-based NLWs, although their use will likely be restricted to MOOTW: First, facilities where chemical-based NLWs are developed, produced, stored, or tested must be declared and may be subject to routine or challenge inspections under the CWC, an important consideration if the nature or existence of such chemicals is to be kept secret. Second, declared RCAs under the CWC could be used by adversaries as a cover for developing lethal CWs. Third, a legal concern regarding the use of any NLW is the liability resulting from the decision not to use NLWs: this liability could be on an individual scale (for example, the case of a soldier who decides to use lethal force instead of non-lethal force in a humanitarian mission) or the liability could be on a much broader scale. It is possible that a nation could bring a case against the US to the UN or World Court claiming the US used excessive force because it had a non-lethal capability but chose to use lethal force instead. Of course, this issue raises the question of a legal or moral obligation always to use the lowest level of force possible. For example, following Desert Storm, the human rights organization, Middle East Watch, argued that since the US had precision-guided munitions, the use of "dumb bombs" was illegal.[18]

In sum, there are definite possible legal and treaty restrictions on the use of NLWs in both MOOTW and MRC. For example, NLWs such as neural inhibitors, gastrointestinal convulsives, neuropharmacological agents, calmative agents, and disassociative hallucinogens, and sedatives, may be considered "temporary incapacitants" and therefore defined as toxic chemicals prohibited by the CWC for any purpose. Notwithstanding, other antipersonnel chemical-based NLWs, such as Sticky Foam, odor-producing chemicals, and lubricants, are likely to be permitted under the CWC. RCAs, which can be used in MRC only against noncombatants, such as in riot control situations or in rear echelon areas outside the zone of immediate combat, will be useful in adjunct MOOTW operations occurring during a MRC. As noted above, biological weapons, both antipersonnel and antimaterial, violate US

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[15] Ibid., Subject: "Legal Review of Barrier Foam," Feb 6, 1995, pp. 1-4.

[16] Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction.

[17] Convention on the Prohibition of Military or Other Hostile Use of Environmental Modification Techniques.

[18] W. Hayes Parks, Special Assistant for Law of War Matters, Department of the Army Office of the Judge Advocate General, "Memorandum for OASD SO/LIC Policy Planning of June 17, 1994, Subject: Nonlethal Technology," cited in Hannigan, Raff, and Paschall, pp. 17-18.

domestic law. Use of antimaterial chemical-based NLWs such as corrosives, embrittling agents, viscosity agents, depolymerizations agents, etc., is probably permitted under the CWC. If the Pentagon interprets the term "toxic chemicals" to include incapacitating NLWs, such as calmative agents, their utility in MRC is questionable. The sole operational utility of chemical-based anti-personnel NLWs will then be in MOOTW, not MRC.[19] Under certain restraints inherent in international law, in some cases, the status of NLWs is ambiguous under the terms of broadly conceived international conventions prohibiting the use of certain classifications of technologies and weapons. For example, it surely would be ironic if "lethal weapons were employed because ambiguities in international law prevented the use of non-lethal weapons."[20]

The use of NLWs in MRC brings with it ethical and moral implications. Just war criteria applied to NLWs strongly indicates that NLWs can make a positive contribution to the US ability to fight a MRC on an ethical basis, and Western just war tradition will provide the central terms of reference for US decision-makers in deciding the use of NLWs. In present day environments, situations arise that blur the lines of distinction between MOOTW and "armed conflict," such as the unexpected use of deadly force by warring factions during humanitarian assistance missions.

Jus ad bellum (war decision law) comprises the ethical criteria for assessing decisions to resort to military force. The seven main criteria that must be satisfied for a war to be considered just are: just cause, right authority, right intention, goal of restoring peace, overall proportionality of good over evil, reasonable hope of success, last resort.[21] *Jus in bello* (war conduct law) sets ethical limitations on the use of military force once the decision to resort to justified military force has been taken. Just conduct of war rests on two main principles of proportionality and discrimination. Military necessity proportionality requires that the means used in fighting a war be reasonably proportionate to the ends pursued. Both war-conduct and war-decision proportionality are concerned with a proper balance between the costs and benefits of using force. War-conduct proportionality is concerned with the strategic and tactical levels of warfare (*raison de guerre*), while war-decision proportionality is concerned with a war's fundamental political and grand-strategic purposes (*raison d'etat*). Discrimination prohibits the direct, deliberate targeting of noncombatants and civilian targets during combat. Civilian damage must be proportionate to the military advantage gained by the military measure.[22]

Using the concepts and criteria of Western just war theory, can the employment of NLWs be consistent with *Jus ad bellum* and *Jus in bello*? With war decision criteria, the nature of specific weapons technologies only figures indirectly into the war-decision criteria with two of the seven main criteria: those are overall military necessity proportionality and reasonable hope of success. NLWs could change a favorable war-decision calculus only if those NLWs failed to live up to their advertised abilities to 1) attain specific combat objectives at much lower human and material costs, failure of which would weaken the case for overall proportionality and 2) provide military commanders with more options and increased capabilities, failure of which would weaken the case for reasonable hope for success. But the injection of NLWs into the MRC equation would make an otherwise just resort to war unjust only if NLWs were to play a major role in the war and by such employment they failed to meet their advertised capabilities. This situation is highly unlikely since more of the weapons employed in any MRC will be lethal ones, with, perhaps, the exception of operations in urban terrain.

With war-conduct criteria the nature of the weapons technologies used in combat figures much more directly. The impact on *jus in bello* is important given that some NLWs may increasingly substitute for lethal weapons for certain MRC missions, while other NLWs will open up new MRC missions altogether. It is probably safe to state that the introduction of NLWs will not violate war-conduct criteria except when NLWs do not work as advertised,

[19] Hannigan, Raff, and Paschall, Ibid., pp. 17-18.
[20] Malcolm H. Wiener, Chairman. "Non-Lethal Technologies: Military Options and Implications," Report of an Independent Task Force, Council of Foreign Relations, 1995, p. x.
[21] James Turner Johnson, "The Just War Tradition and the American Military," in James Turner Johnson and George Weigel, eds., Just War and the Gulf War, Washington, D.C., Ethics and Public Policy Center, 1991, pp. 21-19.

[22] William V. O'Brien, "Just War Doctrine's Complementary Role in the International Law of War," paper delivered at the Symposium on Moral/Legal Limits on Low-Intensity Conflict, US Naval War College, April 9, 1992, pp. 23-25.

that is result in relatively minor, short-term, reversible physiological effects. If NLWs result in nonlethal but debilitating, permanent effects such as blindness or paralysis, long-term unforeseen lethal effects such as cancer or other "unnecessary suffering" will raise serious questions about proportionality. Additionally, combatants must not deliberately use NLWs toward lethal ends in a treacherous or perfidious manner. Military planners and technologists design NLWs with greater discrimination in mind and they must do so in order to receive a favorable legal review prior to acquisition and production.

Nevertheless, infrasound and pulsing-light weapons used in urban operations will not discriminate between combatants and noncombatants, but their effects still may be far less destructive than the effects of conducting the same missions with lethal weapons.[23]

In sum, the use of NLWs in MRC may accomplish three things. First, their use may increase the capabilities of US forces to attain combat objectives while adhering to traditional ethical standards of combat. Second, their use may strengthen the ethical basis of US decisions to resort to the use of military force in MRC. Third, if used improperly, their use may raise questions about proportionality in combat.[24]

The Council on Foreign Relations Task Force considered six inherent risks related to NLWs. The first risk, called the "slippery slope," involves the element of escalation if the use of NLWs leads inadvertently to "unintended and unwanted involvement,"[25] which includes use on a large-scale. This risk can be obviated by a comprehensive understanding of NLW capabilities and limitations, careful and coherent integrated planning, enemy identification and congressional consultation. The second risk is retaliation in forms of NLW technological vulnerabilities, such as computer viruses, induced banking failures, etc. The US dependence on technology increases its vulnerability. The third risk is proliferation. Since much military research and development is based on mimicry, other countries may develop NLWs, which then could fall into the hands of renegades and mercenaries.

However, any restraint in development in the US of NLWs cannot prevent NLW development by other nations. Russia, the United Kingdom, France, Italy, and Israel have made significant inroads in this domain. Unfortunately, terrorists can also find access to NLWs development since components for NLWs are commercially available. The fourth and fifth risks pertain to unrealistic expectations and comparative cost effectiveness. On the one hand, if the public expects bloodless battles and requires employment of NLWs first before lethal means can be used, then disappointment and unnecessary exposure to danger result. On the other hand, NLW employment could certainly increase the safety of US troops and the effectiveness of US actions. Examples include scenarios where a sniper is hidden in a crowd of women and children, preventing US use of lethal fire or when a hostile regime faces internal opposition and the US policy goal is to separate the regime's leaders from the general populace and army. Some individuals have proposed that the casualty-limiting benefits of NLWs could be achieved more quickly and less costly by increasing the precision of lethal arms.

In the final analysis, NLW technologies are not costly compared to potential benefits and when compared to the cost-effectiveness of other weapons systems development, procurement, training and operation. Given the risks related to restraints inherent in international law and conventions, NLW development should conform to constraints such as the banning of lasers that are configured to blind troops or noncombatants.[26]

From the perspective of the American public, there are reasons to support or to reject development and employment of NLWs. Those who favor NLW emphasize that NLWs are humanitarian, minimize human suffering, and save US lives by enabling US forces to disable enemy capabilities without resorting to dangerous air strike missions over the target. For example; they are operationally useful in electronic attack missions and provide an acceptable middle ground between diplomacy and conventional military force by enabling strategic paralysis rather than destruction of the enemy. Countering these positive viewpoints, the public could reject NLWs based on concerns already expressed above that US forces will be expected to use NLWs before lethal force or have to use them while facing a lethally armed adversary and that the US will be perceived as politically weak or the threshold for commitment to foreign conflict by US foces will be dangerously lowered. The guiding principles of necessity and proportionality apply to the use of force for self-defense, to protect noncombatants,

[23] Hannigan, Raff, and Paschall, Ibid., pp.21-23.
[24] Ibid.
[25] Wiener, Ibid., p. ix.

[26] Ibid., pp. ix-xii.

and to facilitate mission accomplishment.[27] During Operation United Shield most provisions of the applicable ROE were unclassified. Each Marine was issued an unclassified ROE card which contained the instructions: "When US forces are attacked by unarmed hostile elements, mobs, and/or rioters, US forces should use the minimum force necessary under the circumstances and proportional to the threat."[28] ROE restrictions pertaining to the use of non-lethal options were arbitrary in nature and did not allow for distinctions between the use of deadly force and all other levels of force. In spite of these restrictions, a consequence of the newness of the employment of NLWs, the Task Force managed to employ properly and appropriately the NLWs they had so diligently trained on prior to the landing in Somalia. A force continuum that allows for the measured application of force between no force and lethal force is rquired. The limitations imposed by the ROE in Operation United Shield did not make sense to the trainers and the operators. If a soldier or Marine has to wait until deadly force is actually authorized, that is, in situations that put life at risk, before a NLW such as a bean bag or rubber baton can be used, then the incentive to restrict response to non-lethal means no longer exists. Confusion on NLW employment was, in part, caused by lack of understanding of their effects.

Fundamental concepts of training and employment of non-lethal weapons systems are more critical than the technology itself because these weapons require quick decisions in stressful situations. Leadership and initiative must be undertaken by the individual troop who may have to decide when to switch from nonlethal to lethal and back to non-lethal force in a given situation with swift changes in activity. For this reason, leadership decisions take on a new magnitude and NLWs should be considered as a component of training across the entire operational spectrum and force continuum. Armed inventions and peace operations should include training in these dual capabilities.

[27] Joint Chiefs of Staff, "Standing Rules of Engagement," of October 1, 1996.
[28] JTF United Shield, Rules of Engagement, Unclassified ROE Card SER #1, 11 January 1995, cited in Lorenz, p. 62.

Emerging Threats, Non-Lethal Weapons and the Industrial Base
By: John B. Alexander

In 1996 the Department of Defense established a formal policy regarding non-lethal weapons and created the Joint Non-Lethal Weapons Directorate (JNLWD) headed by COL Andy Mazzara, USMC, to oversee the programs. The real-world requirements leading to promulgation of the orders were generally derived from recent experiences of US soldiers in peace support operations (PSOs) such as Provide Hope and United Shield in Somalia, Uphold Democracy in Panama, Support Hope in Rwanda, and Joint Endeavor in Bosnia. Due to the similarity of requirements for PSOs to those of law enforcement agencies, there has been extensive coordination between the DoD and the Justice Department on this topic.

The JNLWD, with support of OSD and the services, has created a research, development and acquisition program that, based on available funding, is quite modest by Pentagon standards. As a result, the industrial interest has been, with few exceptions, limited to small, highly specialized companies. These companies develop or produce small quantities of weapons or munitions that are necessary to support current operations. Limited research and development funds also supports new systems and effects studies. Noticeably missing is participation by most major defense industry corporations.

The reality is that peace support operations constitute only a very limited subset of the future operations for which non-lethal weapons will be required. While bad actors will continue to necessitate availability of traditional, highly-lethal military capabilities, many of the merging threats will not lend themselves to application of force via missiles, bombs, and tanks. Instead of adversarial nation-states as the primary threats, we will see social groups that are dispersed, usually based within other countries, but that are capable of threatening our national interests in ways that demand a forceful response. These threats will be exacerbated by an ever-increasing population, difficult-to-stem global migration, and information-aggravated disenfranchisement of technologically developing people. The vast majority of these people are congregating in intensely populated urban areas.

The expansion of terrorism and organized crime are but two of the highly visible examples of these emerging threats. Our ability to apply force will be predicated on our intelligence capabilities that identify and locate the enemy, public acceptance of overt actions, and the weapons systems available. Due to the frequent proximity of substantial numbers of innocent civilians—not to be confused with willing hostages—even precision weapons will have limited utility in destroying targets housing the enemy or his equipment. Rather, will be forced to decide between overkill—risking public outrage—and refraining from taking adequate action—and fostering increased threats. Precision guided munitions with kinetic or concussive warheads can help reduce collateral casualties but still have limited utility on sensitive targets. While not a panacea, non-lethal weapons will offer some new alternatives. Additionally, they would allow new missions such as applying

technological sanctions against potential aggressors that demonstrate our capability, intent, and will to use force.

To incorporate such new and controversial missions, it will be necessary to develop new systems capable of wide area effects, not just aimed at controlling a few individuals. Emphasis probably will be placed on antimateriel technologies that can degrade or destroy an adversary's infrastructure. Such development must be predicated on far broader requirements than currently exist. It will also necessitate more extensive basic research coupled with comprehensive effects testing. That will be followed by a development program significantly larger than is currently contemplated.

To be successful, it is essential that major defense contractors should be drawn into the field as soon as possible. The way to accomplish this is to begin to increase the size of the programs to the point they are sufficiently attractive to gain the attention of corporate executives who a responsible for the bottom line in their respective companies.

Basically, I am suggesting that those involved with non-lethal weapons must generate an industrial base that can meet their future needs. This will not be accomplished without a well thought-out and articulated strategy for future requirements and funding increases that can establish and maintain this base. The military will need to actively engage defense contractors that have the capability to develop advanced systems and have the production capacity to meet sustained output.

The problem is not new or unique to non-lethal weapons. Munitions development and manufacturing has constantly cycled between feast and famine based on the impending outlook for war or peace. What has been learned through many difficult trials, is that we cannot wait until a crisis has arisen to create new munitions or start production. Rather, there must be an existing base from which a surge capacity is possible and programmed. The present capacity for non-lethal weapons is limited to a few rounds of low kinetic energy ammunitions and a few special devices. While adequate for current needs in peace support operations, it is woefully short for imposition of technological sanctions, supporting strategic paralysis, or some of the more comprehensive operations the future will require.

Given the exhaustive testing requirements that have been imposed on new, non-lethal systems, it is imperative that such tests be initiated as soon as possible and continue through fielding. Comprehensive knowledge about the effects of non-lethal weapons on humans and the environment is essential. However, it must be remembered that these are weapons systems, not health care devices that are being developed. The search for the perfect weapon that will never have unwanted adverse effects will stymie the fielding of adequate systems that are sorely needed.

While non-lethal weapons are currently controversial, units in peace support operations are demonstrating their utility. Given in the nature of unconventional threats we will likely face in the future, new missions must be anticipated. While establishing current needs for non-lethal weapons, we must concurrently develop the industrial base necessary to support the complex future requirements.

Dr. John Alexander, a retired US Army colonel, chaired Non-Lethal Defense I, II, & III conferences. He is the author of the forthcoming book, *Future War: The Non-Lethal Factor,* St. Martin's Press, Fall 1998

FUTURE REQUIREMENTS & DEVELOPMENT OF A NON-LETHALWEAPONS INDUSTRIAL BASE

Presented To:

Non-Lethal Defense III

Presented By:

John B. Alexander, Ph.D.

Colonel, US Army (Retired)

Johns Hopkins Applied Physics Laboratory

26 February 1998

"It's a non-lethal area neutralizer"
Michael Crichton
The Lost World

" Our people were under orders to use nonlethal force"
Tom Clancy
Debt of Honor

HAT'S NEW?

- *WORLD GEOPOLITICAL SITUATION*
- *MATURITY OF TECHNOLOGY*
- *OPERATIONAL EXPERIENCE*
- *DESERT STORM TECH DEMO*

REASONS TO CARE ABOUT NON-US CASUALTIES

*** WE WANT A FRIENDLY POPULATION**
(AFTER THE OPERATION)

*** IMPACT ON A COALITION**
(REMEMBER THE BUNKER IN BAGHDAD)

*** LONG-TERM GOALS REGIONAL STABILITY**
(VICTIMS HAVE LONG MEMORIES)

*** CONSCRIPTS HAVE LITTLE POLITICAL MOTIVATION**
(THEY MAY BE IN MILITARY FOR ECONOMIC REASONS)

*** AMERICAN VALUES & SENSE OF FAIRNESS**
(A FINE LINE BETWEEN WINNING BIG & A MASSACRE)

NON-LETHAL WEAPONS & The INDUSTRIAL BASE
Where are We Now

- Most Major Defense Contractors are not Engaged
- Requirements are Slow to Evolve
- The Money is Comparatively Small
- Legal Risks are being Accentuated
- Efficacy Debate Generates Concern about Market Stability

NON-LETHAL WEAPONS & The INDUSTRIAL BASE
What Needs to be Done

- Produce Hard Requirements Documentation
- Increase Funding to Attract Major Players
- Conduct Studies that Demonstrate Multilevel Needs
- Incorporate NLW in Standard Training Courses
- Reward Innovative Research & Development
- Purchase Beyond Established Requirements
- Resolve Legal Issues ASAP
- Increase Political Support

Ethical Issues Associated with Non-Lethal Weapons

- Non-Lethal weapons as precursor to lethal weapons
- Possible permanent Injuries
- Unintentional fatalities
- Increased williness to use force
- Possible Treaty Violations
  - Chemical weapons
  - Biological weapons
  - Blinding weapons

Many believe there are
"Fates worse than death."

RECONSIDERATION OF ISSUES

- WHAT PROBLEM ARE YOU SOLVING?
- MOST ARE BASED ON EMOTION VS. FACTS
- BLAME TECHNOLOGY FOR HUMAN PROBLEMS
- CHEMICAL & BIOLOGICAL AGENTS HAVE PEACEFUL PURPOSES
- FUTURE ADVERSARIES ARE NOT SIGNATORIES TO TREATIES
- MORE OPTIONS ARE PREFERABLE TO LESS

THE PRIMARY QUESTION SHOULD BE:

COMPARED TO WHAT?

NATIONAL SECURITY ISSUES

- Redefinition of WINNING
- Complex, Often Limited Objectives
- Extremely Broad Spectrum of Threats & Circumstances
- Perception Management
- Coalition Engagements vs. Unilateral Action
- Materiel Integrity
- Personal Loyalties and Commitment
- NGO Hi-Tech R&D Threats
- Recruiting

C4I an Order of Magnitude More Complex

SUMMARY

THE NATURE OF CONFLICT IS CHANGING

- There are still Conventional Bad Actors

Future Threats are more Diverse and Complex

WE WILL NEED TO REDEFINE "WINNING"

NON-LETHAL WEAPONS *WILL BE REQUIRED AS <u>PART</u> OF THE SOLUTION IN USE OF FORCE*

TACTICAL - OPERATIONAL - STRATEGIC

INTENT - CAPABILITY - WILL!!!

NON-LETHAL INDIVIDUAL WEAPONS INSTRUCTOR COURSE

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22 January 1998

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NON-LETHAL INDIVIDUAL WEAPONS INSTRUCTOR COURSE

INTRODUCTION

With every major shift in technology or geopolitical environment there comes a need to develop change in the tactics, techniques and procedures used by the military forces of today. Introducing non-lethals has been met with it's share of resistance. Phrases like "operations other than war" (OOTW) and "support and stability operations" (SASO) have introduced themselves to each services vocabulary requiring of service members more than just two choices in regards to the use of force. Non-lethal initiatives provide a wide range of options to commanders, but do not replace traditional weapons. This point is made clear by the Department of Defense (DoD) Directive 3000.3 "Policy for Non-Lethal Weapons" which clearly states:

".. the availability of non-lethal weapons will not limit the commander's inherent authority and obligation to use all necessary means available and to take all appropriate action in self defense."

The concept of using non-lethals has been available for years, only the technology changes. To further exasperate resistance to the new technology on the battlefield, organizations within the DoD are developing different training plans, tactics, techniques and procedures for the tactical employment of non-lethals. The purpose of this paper is to outline the need for one DoD training strategy and propose a solution.

BACKGROUND

In 1995, Lieutenant General Anthony Zini, U. S. Marine Corps was tasked with protecting the final withdrawal of United Nations Forces from Somalia. To accomplish Operation United Shield, his organization explored the prospects of using non-lethals. Once the need was identified, a quick response to the task of fielding non-lethal capabilities became the issue. The military consulted civilian and federal law enforcement agencies who were considered the "subject matter experts" (SME) in the use of non-lethals against a forceful, aggressive, but not quite "deadly" adversary. A Non-Lethal Technology Mobile Training Team (MTT) comprised of highly trained and skilled senior staff noncommissioned officers was formed under the auspices of the G-7, I MEF, Camp Pendleton, California. Once deployed, integrated and trained, Marines used this non-lethal capability in and around Mogadishu. Although the use of non-lethals was minimal, it's impact was positive and determined the need to have this technology available to deploying forces.

Non-lethal was a priority initiative in the Commandant of the Marine Corps' 1996 planning guidance. The Commandant's War Fighting Lab (CWFL) and other Headquarters Marine Corps sponsored agencies continued to conduct research and experiments with contemporary and materializing technologies within the non-lethal arena. One of these initiatives was to provide a "non-lethal capability set" as organizational equipment to each Marine Expeditionary Unit (MEU). The experiment was time consuming and tedious but resulted in a "suite" of gear procured and issued to the deploying Marine units. This equipment and philosophy initiated the requirement to train Marines in more than two options as related to the use of force. As an analogy, the "on-off" switch had to be replaced with a "rheostat". Training became a serious issue - not only for the service member responsible for using this technology, but for instructors ultimately responsible for teaching it.

Within a year of the Operation United Shield MTT, the non-lethal training capability that I MEF had experienced began to evaporate with the normal change of station orders and retirement of it's members. I MEF G-7's Non-Lethal Action Officer harnessed the knowledge of these Marines and developed a training capability within the organization. Military Police Company, 1st Force Service Support Group, Camp Pendleton, California organized and trained a non-lethal instructor cadre. Once institutionalized, they trained units within each MEU, but because a "suite" of non-lethal munitions did not exist to support such training, a significant amount of collective corporate knowledge diminished. In compliance with recommendations and support of the I MEF G-7 Non-Lethal Action Officer, the Military Police School, Marine Corps Detachment, Fort McClellan, Alabama initiated the development of the Non-lethal Individual Instructor Course (NIWIC).

DISCUSSION

In managing limited human resources, DoD can not justify having different training plans for different services. The NIWIC course is proposed as a DoD training standard.

There's a definite gap between "shoot" and "don't shoot". Non-lethal technology is the way to bridge that gap. Site visits, MTT's, and New Equipment Training Team's (NETT) to the operating theaters of Haiti, Bosnia, Hungry, Germany as well as visits to U. S. installations, determined the requirement for non-lethals and the training of tactics, techniques and procedures was evident.

At the 1997 Non-Lethal Defense Conference II, General John J. Sheehan, U. S. Marine Corps commented, "Whether it's US Forces in Somalia, IFOR troops in Bosnia, QRF in Panama or either Haiti or Guantanamo Bay Cuba, we have all faced operational situations where nonlethal weapons and capabilities were needed but unavailable." Non-lethal weapons are intended to have one, or both of the following characteristics: (1) They have relatively reversible effects on personnel or material; and (2) they affect objects differently within their area of influence. Non-lethals are developed to discourage, delay, or prevent hostile actions; limit escalation; take military action in situations where the use of lethal force is not the preferred; better protect our

forces; and temporarily disable equipment, facilities, and personnel. Because of this, substantial effort must be made to training forces in their use as they relate to tactical applications.

The task at hand is to "step outside the box," revisit the application of force in today's military operations and establish NIWIC as the DoD Training Program. In doing so, four substantial observations were made and classified as requirements:

(1) The identification of a requirement for an instructor cadre organic to the serving unit, capable of instituting initial skill training and sustainment training.

(2) A program that encompasses all levels of continuum of force as it relates to non-lethals. This program must be supported in theory as well as legally, whether in a courtroom or on CNN.

(3) The program must consolidate "new equipment training" and tactics, techniques and procedures training.

(4) Most importantly, non-lethal training standards must be DoD wide to better support a joint commander and joint environment. .

Based on these requirements, the initiative to develop a "train the trainer" course began. Along with numerous training organizations, operational units and research and development agencies, the concept for NIWIC was drafted. The focus is to certify instructors to conduct training with non-lethals as determined by the unit commander.

Psychomotor skills involve mental and physical skills, physical skills that require the learner to execute muscular actions. Most often these actions are in response to another person's opposing action. An individual's decision to use or not to use deadly force is no longer merely a tactical decision, it was determined that teaching psychomotor skills in judgmental scenarios would be a task. Due to the "CNN factor," the implications of a decision is capable of being broadcast throughout the world. Additionally, we asked the question "What should instructors know and be able to do?" A course designed to enhance an instructors knowledge, skills anu abilities to present psychomotor skills can answer that question in five distinct statements.

(1) Instructors are committed to students.

(2) Instructors know the subjects they teach and how to teach those subjects.

(3) Instructors are responsible for managing and monitoring learning.

(4) Instructors think systematically about their practice and learn from experience.

(5) Instructors are members of learning communities.

With these elements is a course which provides the participant a full spectrum view of "how and what we learn as instructors effects how and what we teach and train others". Based on this philosophy, individual training standards (ITS) were developed to meet the requirement of training service members with non-lethal weapons in support of OOTW and SASO. Forces assigned in theaters such as Bosnia or Haiti can be in a very difficult situation. Obviously having sufficient power to counter any armed adversary, how do they respond to the unarmed demonstrator? Built around the theory of force continuum, these standards satisfy the federal force continuum model as it relates to law enforcement and military operations other than war. These standards provide the answer to the previous question. Individual training standards of NIWIC are:

NLWS.1.1	DETERMINE THE APPROPRIATE LEVEL OF FORCE REQUIRED.
NLWS.1.2	DETERMINE APPROPRIATE METHOD FOR DISSIPATING A CROWD / CIVIL DISTURBANCE
NLWS.1.3	PROVIDE NON-LETHAL (NL) CAPABILITY TECHNICAL EXPERTISE TO THE COMMANDER
NLWS.2.1	UTILIZE VERBAL COMMUNICATION TO MANAGE AGGRESSIVE BEHAVIOR
NLWS.2.2	EMPLOY OLEORESIN CAPSICUM (OC)
NLWS.2.3	UTILIZE OPEN HAND CONTROL TECHNIQUES
NLWS.2.4	SUPERVISE RECOVERY TEAM EMPLOYMENT
NLWS.2.5	EMPLOY IMPACT WEAPONS
NLWS.2.6	EMPLOY HAND THROWN STINGER GRENADE
NLWS.2.7	EMPLOY STINGER GRENADE VIA 12GA LAUNCHING CUP
NLWS.2.8	EMPLOY HAND THROWN FLASH BANG
NLWS.2.9	EMPLOY NON-LETHAL 12GA MUNITIONS
NLWS.2.10	EMPLOY NON-LETHAL 37/40MM MUNITIONS

We often think "to be effective, it must be shot from a weapon". To disperse a crowd of Bosnians who are becoming disruptive on a cold, winter day, one needs only to find a water hose. Once wet, no one in their right mind would stand outside for very long.

Today's OOTW missions put service members in close proximity to agitators and aggressors. Whether at a check point in Port-a-Prince or, a food distribution point in Somalia, the space (stand off distance) between local nationals and service members does not always lend itself as being feasible to use conventional methods should the requirement of force be necessary.

A soldier directing a crowd at a food distribution point can unknowingly agitate the group by what is said and how it is said over a bullhorn. Knowing the importance of applying verbal and nonverbal communications skills is considered important. A Marine at a check point should be capable of defending himself against combative individuals without "breaking bones" or "stomping on heads." Simple "open hand control techniques" can make the difference in a televised incident. An airman with a riot control baton should be capable of more than just "hitting" people. Knowing proper striking techniques, striking points, defensive techniques and control techniques are essential. Riot control training has been available for years. Simple "romp 'n stomp" is very effective when dealing with a crowd, riot, or mob. Knowing the difference between a crowd, riot and mob is just as important. Knowing what motivates a mob, what initiates a riot and the possible resultant effects of a crowd provides service members with additional tools that prove helpful in dealing with these situations. The service member trained in crowd dynamics is a positive asset to the joint operation commander.

These skills don't present themselves by "exiting the barrel of a weapon" but are essential when dealing with aggressive individuals. They are "non-lethal" and if used correctly can be a positive asset to commanders in any environment. There is a distinct difference between "Get the f**k out of here!!" and "Would you mind leaving the area?" Training service members to do the later is a responsibility that is beneficial to a joint commander, and supports any operational situation found in an OOTW and SASO environment.

The NIWIC Program of Instruction (POI) provides this type of training. Consisting of approximately 120 hours of instruction and practical exercises, this program covers the entire spectrum of force continuum. The result is an instructor who is certified, capable, equipped and motivated to provide any operational commander with trained service members. Developed to support the individual training standards, the program provides a foundation allowing for additional skills to built. The following is a brief summary of sub courses:

<u>Force Continuum</u> This sub course introduces the student to the federal force continuum model and the use of force. Upon completion, the student will be able to instruct others on force continuum and the escalation of force.

<u>Crowd Dynamics/Crowd Control</u> This sub course outlines the differences between crowds, mobs and riots and teaches the student basic crowd control techniques which will easily be applied to various situations. Upon completion, the student will be able to instruct others in regards to crowd dynamics and crowd control techniques. The student will be familiarized with classical tactics and techniques, but will also consider nontraditional and small unit application.

Communication Skills This sub course will teach the student how to instruct others on techniques to de-escalate situations by using verbal skills and crisis intervention techniques.

Oleoresin Capsicum Aerosol Training This course will teach the student how to safely and thoroughly instruct others on the uses of oleoresin capsicum aerosol sprays and other riot control agents. The student will gain an appreciation for decontamination requirements, legal/policy considerations, and tactical considerations imposed by detainees / casualties.

Open Hand Control This sub course will teach the student to employ pressure point control techniques, unarmed self defense measures, weapon retention techniques and other submission / restraint / search techniques. Upon completion, the student will be certified to instruct the aforementioned subjects.

Impact Weapons This sub course will teach the student in the uses of various impact style weapons (batons) to include the rigid straight baton, collapsible straight batons, side handle batons and riot control batons. Upon completion, students will be certified to instruct the use of these impact weapons.

Introduction to Military Working Dogs This sub course will teach the student how to instruct the student on the role of military working dogs and the potential support available to forces requiring non-lethal force options.

Law of War / Rule of Engagement This sub course will teach the student how to instruct classic law of war and standard rules of engagement. Knowing that rules of engagement differ from individual operational theaters, instructors are encouraged to solicit support from assigned Judge Advocate General (JAG) officers. The content of this sub course not only subjects the student to rules of engagement and the law of war but how non-lethals should be viewed as they relate to rules of engagement / law of war.

Non-lethal Munitions & Employment This sub course will teach the student how to instruct the non-lethal munitions available. Students will participate in live fire exercises and upon completion of the course will be certified to instruct others on the employment of such munitions whether type classified or not..

Barriers / Physical Security Measures This sub course will teach the student how to instruct others on barriers and physical security measures available to tactical forces which complement the use of non-lethal force or mitigate the need for deadly force. Upon completion, the student will be able to instruct others on the employment of barriers/physical security expedients.

Tactics This sub course will teach the student how to instruct others on mounted / dismounted tactics and civil disturbance as they are related to the use of non-lethal munitions. Upon completion, the student will be able to instruct others on mounted / dismounted tactics.

Once instructed and trained on the sub courses, NIWIC students are evaluated in establishing "real world" scenarios, enhancing their skills of being capable of executing an entire, non-lethal training exercise.

The course was developed as a resident program at Fort McClellan, Alabama established at the Marine Corps Detachment. The Commandant, United States Army Military Police School (USAMPS) determined the POI to be relevant and committed to logistically supporting a Marine unique course at Fort McClellan. USAMPS did not identify a need to start Inter-Service Training Review Organization (ITRO) discussions until equipment and munitions are classified and become part of U. S. Army organizational equipment. While the parochial needs of one service may have been met by this decision, the collective needs of the DoD suffer. Upon receipt of USAMPS logistical and garrison support, the Course Descriptive Data (CDD) was finalized and submitted to the Training and Education Branch, Marine Corps Combat Development Center, Quantico, Virginia for approval.

SUMMARY

Non-lethal technology can reduce unnecessary casualties, especially civilian fatalities. Although it is not a replacement for lethal force, it is a necessity and should be part of the "tool kit" we provide deploying forces. With sending this "tool kit," there is the untiring responsibility to effectively and consistently train all service members equally. The training must be substantial, practical and standard throughout all branches of the Armed Forces and supporting agencies. The elements previously outlined must now be introduced as "objectives":

(1) Develop an instructor cadre organic to the serving unit, capable of instituting initial skill training and sustainment training.

(2) Ensure a program encompasses all levels of continuum of force as it relates to non-lethals. This program must be supported in theory as well as legally, whether in a courtroom or on CNN.

(3) Ensure the program consolidates "new equipment" training and tactics, techniques and procedures training.

(4) Mandate non-lethal training standards are DoD wide to better support a joint commander and joint environment. .

These objectives must be met with a standard course of instruction that formally identifies individuals as Non-lethal Instructors for use by all commanders. If not, a dire injustice is done not only to the deploying service member but to the joint environment as a whole. Non-lethal technology provides the opportunity to expand military responses to a variety of missions ranging from low intensity conflict to operations other than war to domestic terrorism.

Due to the wide variety of technologies and missions, the Joint Non-Lethal Weapons Directorate was developed as the focal point for all DoD non-lethal weapons activity. One advantage of this joint office is the effect it can have on preventing the duplication of efforts. With respect for this concept, the same should hold true in regards to training. A single, joint oriented, formal non-lethal instructors course supported by the Joint Non-lethal Weapons Directorate should be institutionalized to support all Services and the U. S. Special Operations Command.

POINTS OF CONTACT

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The Marine Detachment, Fort McClellan has established a Non-Lethal Web Site which can be found at: **www.ftmc-marine.army.mil**

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Current Non Lethal Materiel Programs

Presented by

Anthony T. Desmond

Program Management Engineer

Army Materiel Command

Non Lethal Materiel Program

Joint Vision 2010

"To protect our vital national interests we will require strong armed forces, which are organized, trained, and equipped to fight and win against any adversary at any level of conflict. Concurrently, we must also be able to employ these forces in operations other than war to assist in the pursuit of other important interests".

NL Operational Concept

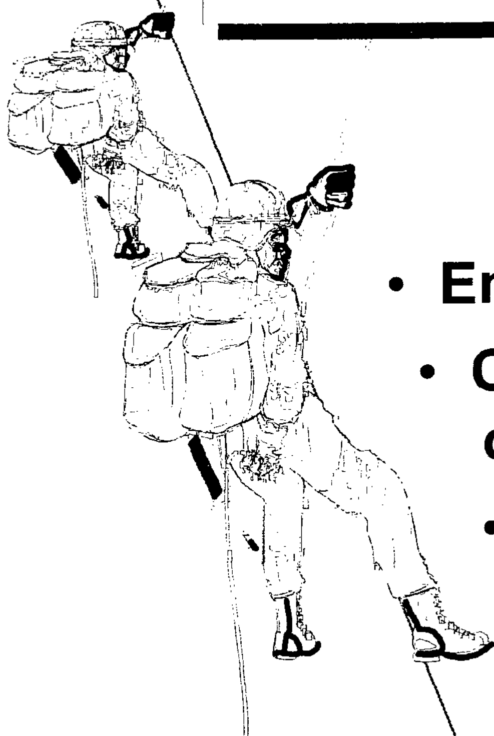
Guiding Principles

- *Enhance Operations*
- *Leverage "High-End" Technologies*
- *"Rheostatic" Capability*
- *Policy Acceptability*
- *Reversible Personnel Effects*
- *Augment Deadly Force*
- *Expeditionary Character*
- *Focus on Tactical Applications*
- *Applicability Across the Range of Military Options*

BLWE ongoing at DBBL to Validate Operational Concept Vignettes

Mission Need Statements

The US Marine Corps and Army have Approved Mission Need Statements



Areas of Commonality include:

- **Enhancing Operational Capability**
  - **Conduct Operations across the Range of Military Operations**
    - **Missions include: *Cordon and Search, Humanitarian Assistance, Peace Enforcement, Peace Keeping***
      - **Systems that provide flexible means of response**

Goals

FY95 FY00 FY 05 FY10

Short Term

Put a “family” of multi-purpose, easily trained, and inexpensive non-lethal tools which can be employed from existing weapons platforms into the hands of the soldiers in order to satisfy immediate user requirements.

Long Term

Improve on solutions to immediate requirements
Anticipate and provide solutions to future user requirements.

Strategy

FY95 FY00 FY 05 FY 10

Develop & Advance Technologies

Insert into Existing Weapon Platforms

Develop NL Weapon Platforms

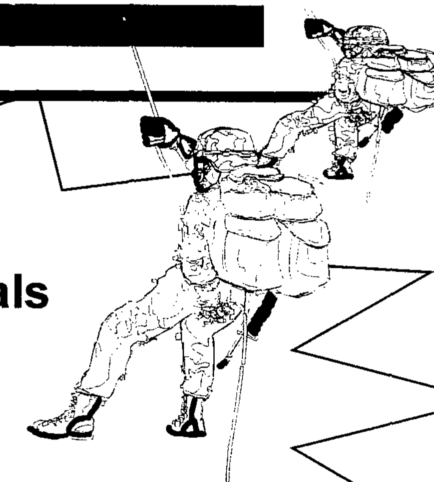
Concept Evaluation Program

ACTDs, BLWEs, JLOEs, AWEs

Transition to PM/PEO

Provide Capabilities to:

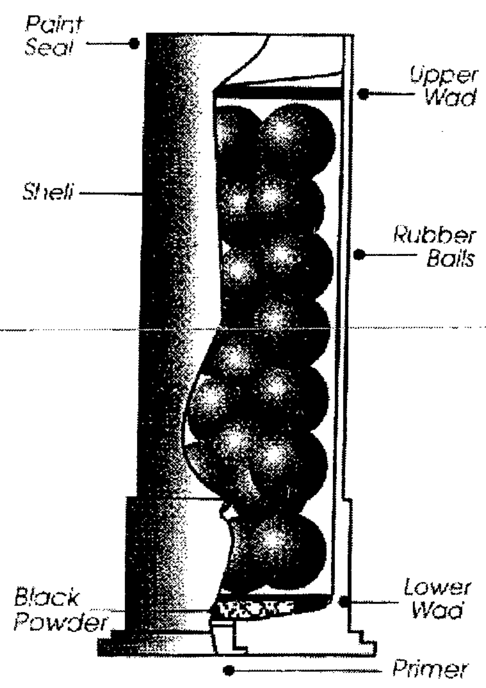
Stop a Vehicle
Incapacitate/Stop Individuals
Distract Individuals
Seize Individuals
Control Crowds
Block an Area
Disarm/Neutralize Equipment



FY 98/99 Service Program List

1. *NL Crowd Dispersal (M203) (Army/ARDEC)*
2. *Acoustic Target Effects (Army/ARDEC)*
3. *MCCM (NL Claymore) (Army/PM-MCD)*
4. *Stoppers*
   a. *Ground (Army/ARL)*
   b. *Maritime (Navy/NSWCDD Dahlgren)*
5. *Speed Bump (Net) (Army/PM-MCD)*
6. *Area Denial Technology (Air Force/AFRL Phillips Research Site)*
7. *66mm Vehicle Launched Payload (Army/PM Smoke)*
8. *UAV NL Payloads (Navy/NSWCDD Dahlgren)*
9. *Bounding NL Payloads (Army/ARDEC)*
10. *Canister Launched Area Denial System (CLADS) (Army/PM-MCD)*
11. *Foam Applications (Army/ERDEC)*
12. *Acoustic Generators (Army/ARDEC)*
13. *Vortex Ring Gun (Army/ARL)*
14. *Underbarrel Tactical Payload Delivery System (Army/ARDEC)*

NL Crowd Dispersal (M203)



Category: Kinetics, Anti-Personnel

Concept of Operation: Crowd Control Incapacitate Personnel

Technologies: Blunt Impact Trauma

Program Objectives: To Type Classify a 40mm Non-Lethal Crowd Dispersal round for the M203 Grenade Launcher

Acoustics Programs

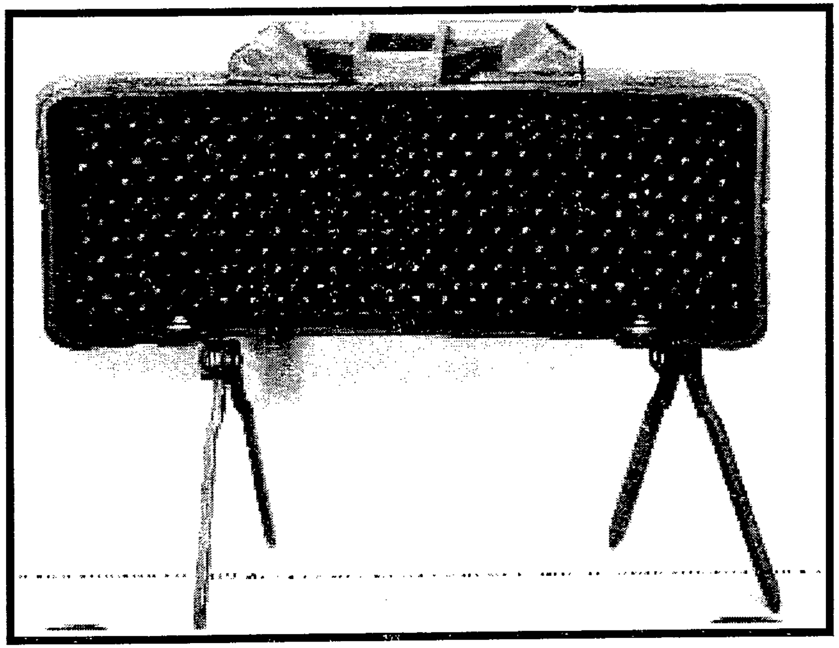
Category: Directed Energy

Concept of Operation: Provide a rheostatic crowd control and/or area denial capability, to be determined based on results of concept exploration studies. Options include a crew-served or vehicle mounted weapon, or a munition delivered by UAV/UGV, artillery, or area denial munition.

Technologies: Pressure wave generation, impedance matching and target coupling, target effects..

Program Objectives: Provide the warfighter with a rheostatic weapon.

Modular Crowd Control Munition (NL Claymore)



Category: Kinetics, Pre-emplaced munitions.

Concept of Operation: Crowd control and vehicle self protection
- NL version of M18A1 Claymore

Technologies: Propelling charge with rubber balls and flash-bang.

Program Objectives: Transition design of M18A1 APERS into a device to produce sting effect at 5-15 meters with flash and bang.

Stoppers (Ground)

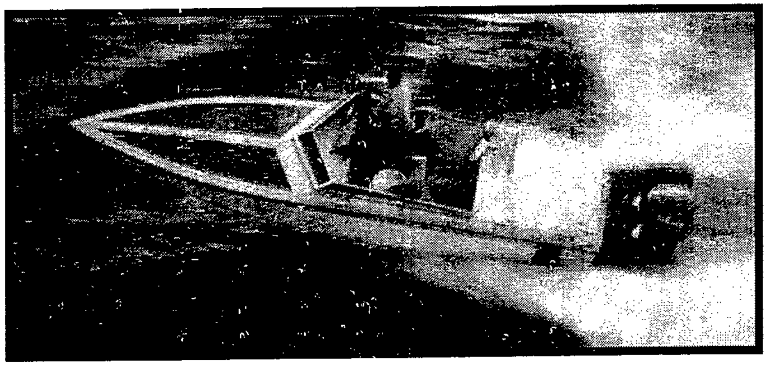
Category: Directed Energy

Concept of Operation: Stop a vehicle engine by disabling electronic components

Technologies: Swept frequency microwave transmitter; direct injection device (high voltage pulse)

Program Objectives: Develop a lightweight, compact device capable of stopping both military and commercial engines.

Stoppers (Maritime)



Category: Maritime Vessel Stopper

Concept of Operation: Provide a capability to non-lethally deter, disrupt or stop suspect surface vessels of interest:

- Littoral scenarios (force protection)
- Coastal/River Tanker (interdiction)

Technologies: Various anti-material/ anti-personnel agent technologies including entanglers, foams, foreign object damage, taser, etc.

Program Objectives: To develop a device that will disable small inboard diesel powered surface vessels.

Speed Bump (Net)

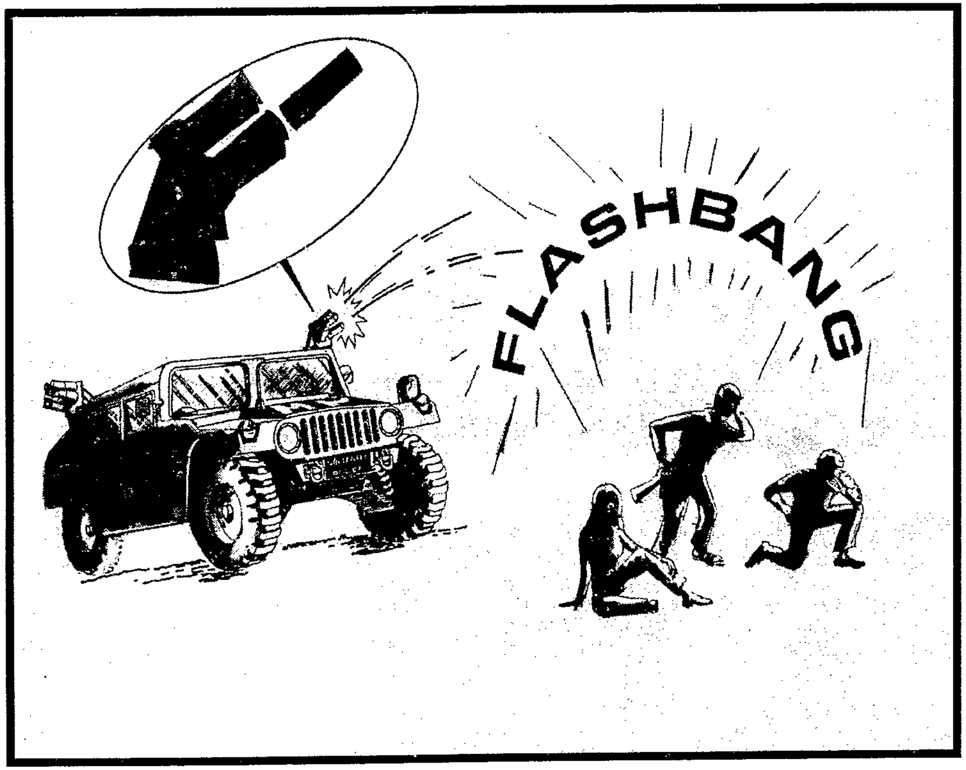
Category: Vehicle Stopper

Concept of Operation: Pre-emplaced at key vehicle entry points without impeding flow of traffic. Command-activated to capture suspect vehicle without serious injury to occupants.

Technologies: Pneumatic telescoping poles, vinyl webbed arresting net, disc braking system.

Program Objectives: Use a pre-emplaced vehicle immobilizing "Speedbump" system to stop a 7,500 lb vehicle traveling at 40 - 60 mph within 200 ft, without serious injury to the vehicle occupants.

66mm Vehicle Launched Payload



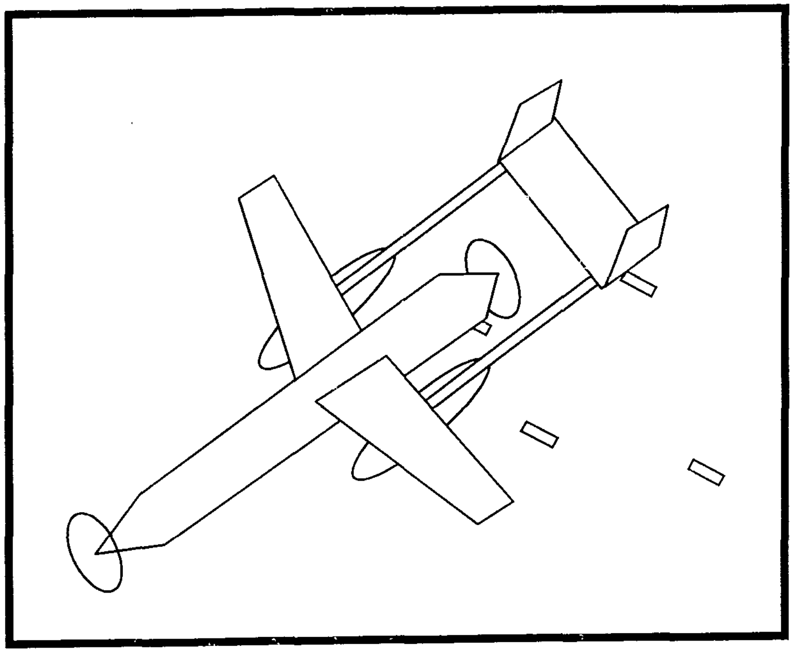
Category: Kinetics

***Concept of Operation*:** System employed at standoff from vehicle to deter rioting crowds

***Technologies*:** Kinetics, Pyrotechnics

Program Objectives: Develop NL flashbang payload for 66mm Vehicle Launched system for crowd control purposes.

UAV NL Payloads



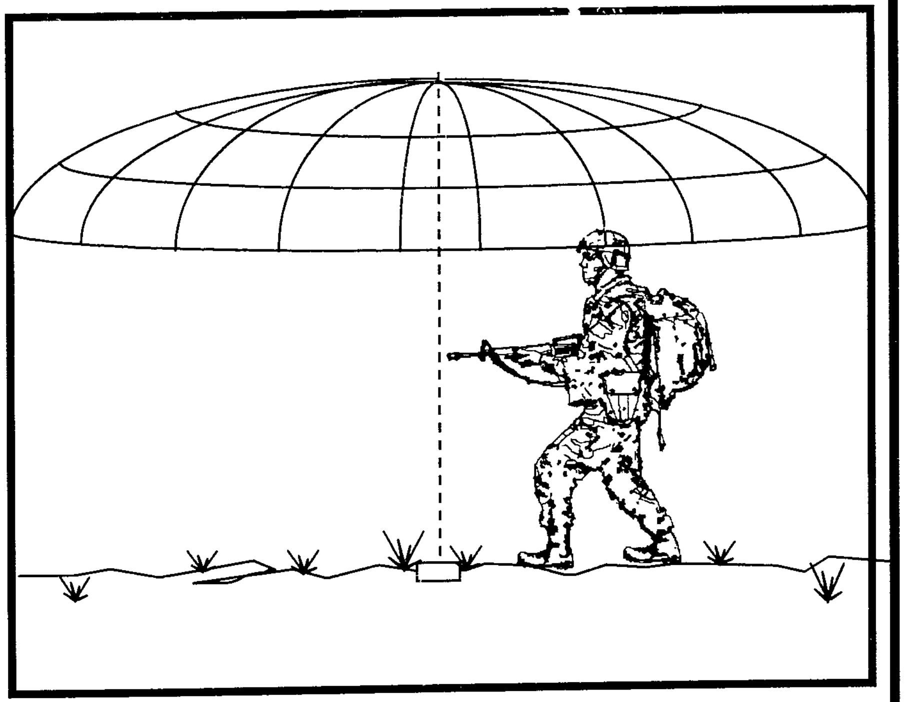
Category: NL Delivery Methods

Concept of Operation: Use UAVs to deliver non-lethal payloads in support of MOOTW

Technologies: UAV Systems, Dispenser Mechanisms, Non-Lethal Payloads, Accurate Delivery.

Program Objectives: To develop a non-lethal payload dispensing capability for UAVs.

Bounding NL Munition



M16A2 Hand Emplaced "Bouncing Betty"

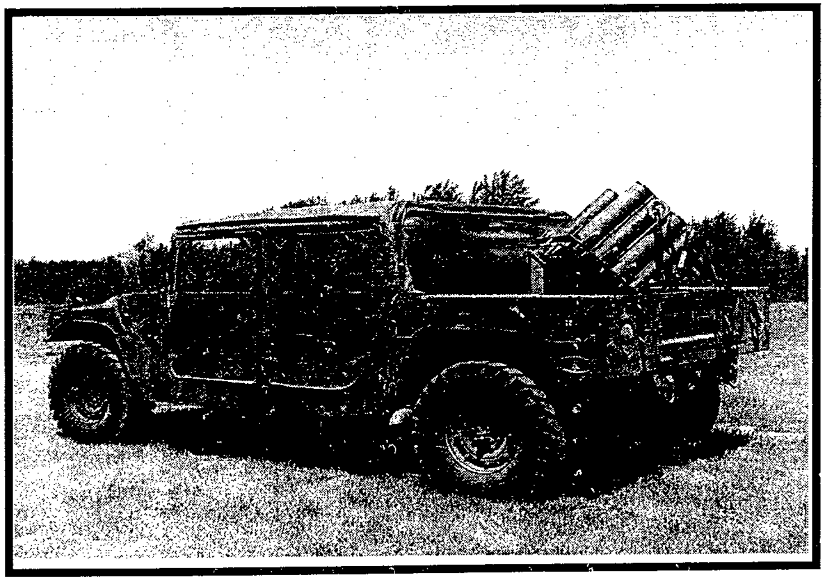
Category: Entanglements, Site Security/ Perimeter Defense.

Concept of Operation: Item functions similar to tactical bounding APERS mine (M16A2) but with delay/deter payloads (add delay to APL alternatives).

Technologies: Rapid, reliable activation (IR sensor, trip wire) for high reliability capture. Potential immobilization enhancers - sting balls, malodorants, markers and nets.

Program Objectives: To demonstrate the deployment of a delay/deter payload from a tactical bounding munition.

Canister Launched Area Denial System (CLADS)



Category: Entanglement (AP/AM)

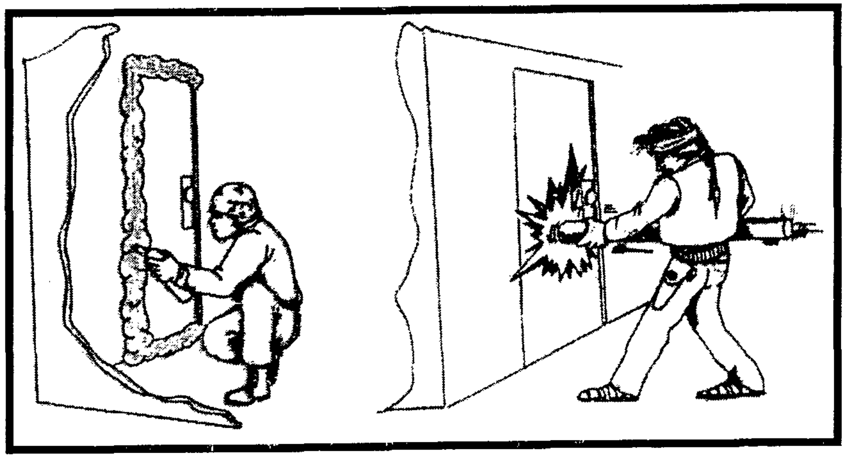
Concept of Operation: Rapidly deploy Non Lethal (NL) payloads from the Volcano Mine Dispenser system mounted on a HMMWV, utilizing a 20 canister launcher rack.

Technologies:

- Payload selection (various)
- Modular Payload

Program Objectives: Demonstrate and validate the dispensing of NL payloads (concertina, bounding munition, malodorous, etc.) from a Volcano system utilizing a 20 canister rack, mounted on a HMMWV.

Foam Applications



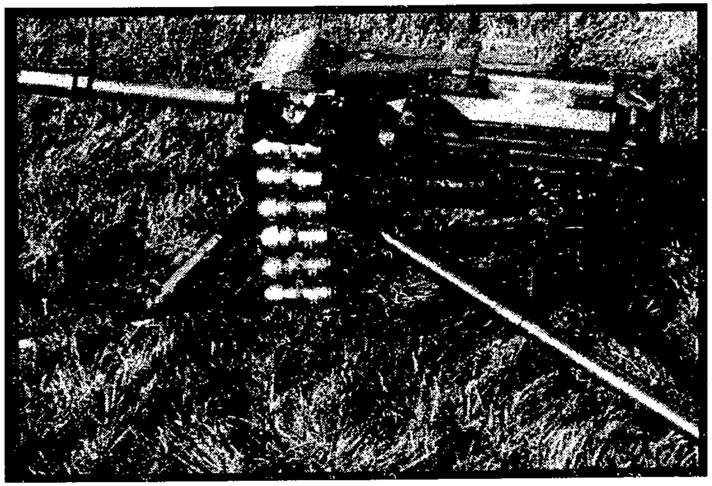
Category: Rigid Foam and Epoxies

Concept of Operation: Rigid foams for area denial and quick seal of doors and window. Will also be used as an anti-materiel agent for small arms and other equipment.

Technologies: Accelerate polyurethane/epoxy cure times, dispenser/ packaging.

Program Objectives: To formulate/design and field a fast curing rigid foam and dispensing system

Vortex Ring Gun



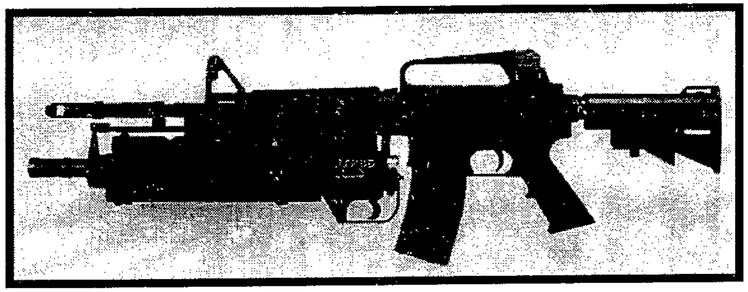
Category: Vortex Ring Gun (VRG)

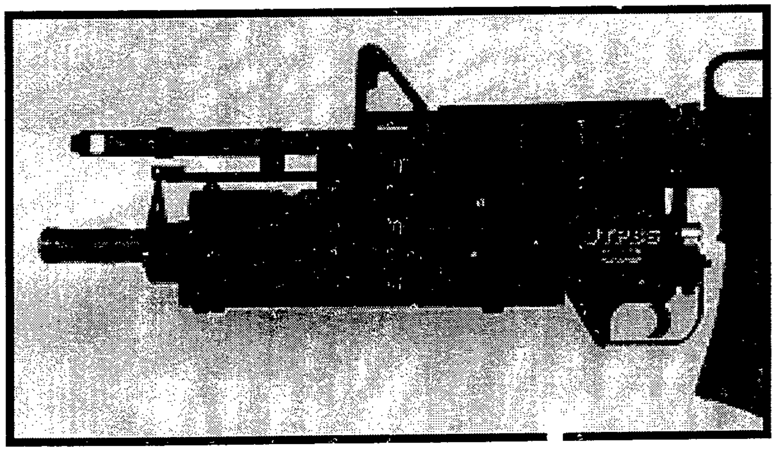
Concept of Operation: Apply vortex ring gas impulses with combined target effects (flash, concussion and non lethal agents and/or markers) to provide the user with area denial and crowd control capability beyond current NL kinetic munition ranges.

Technologies: Vortex ring formation and propagation, entrainment of nonlethal and marker agents in vortices, blank MK19-3 40 mm round development.

Program Objectives: Provide the user with a retrofit kit for the MK19-3 automatic 40 mm grenade launcher to enable quick changes between lethal and non lethal operations employing blank cartridges, a supersonic nozzle and liquid agent reservoir.

Under-barrel Tactical Payload System





Category: Kinetics - Point and Area Target

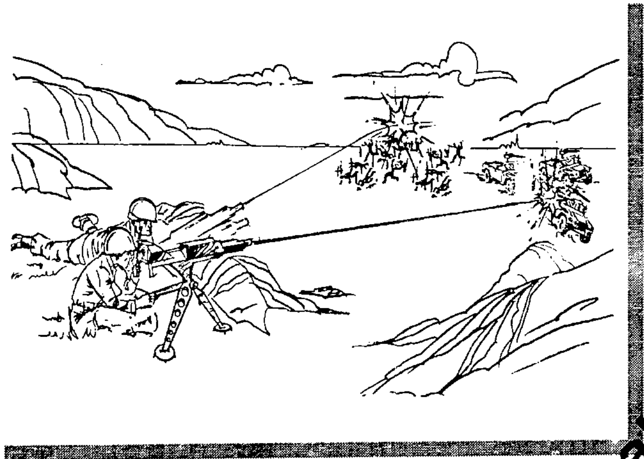
***Concept of Operation*:** Neutralize selected targets and areas at a distance of 30-100 meters with a modular, secondary NL multi-shot armament system. Near instantaneous change over to M16A2/M4's lethal fire.

Technologies:

- Pneumatic (compressed-air propulsion)
- Various payloads (impact, markers (UV, IR, RF, visible), malodorants)

Program Objectives: To integrate an under-barrel non lethal (tactical paint-ball type) weapon system on the M16A2/M4 for Crowd Dispersal, Point Target, and MOUT.

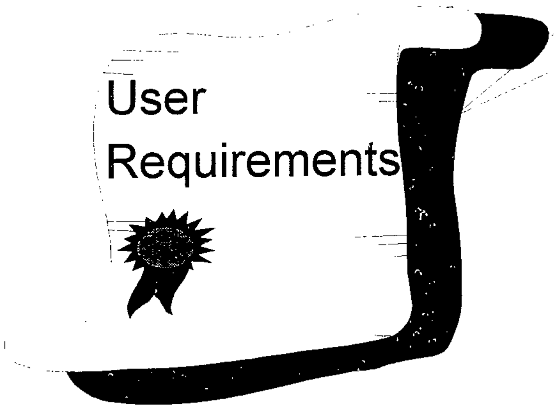
Capability/Technology Roadmap



Technologies	Incapacitate/Stop Individual(s)	Distract Individual(s)	Seize Individuals	Stop a Vehicle	Block an area	Control Crowds	Disarm/Neutralize Equipment
Acoustics	✓	✓			✓	✓	
Kinetics	✓	✓				✓	
Entanglements	✓		✓	✓	✓		
Vehicle Stoppers				✓			✓
Riot Control Agents	✓	✓	✓		✓	✓	

Conclusions

Specific Recuirements critical to "drive" materiel development and acquisition



Must be able to control civilians/noncombatants in order to succeed in the missions of tomorrow


INFANTRY

Purpose

- Provide an Infantry perspective on tactical non-lethal requirements

The Enduring Infantry Mission

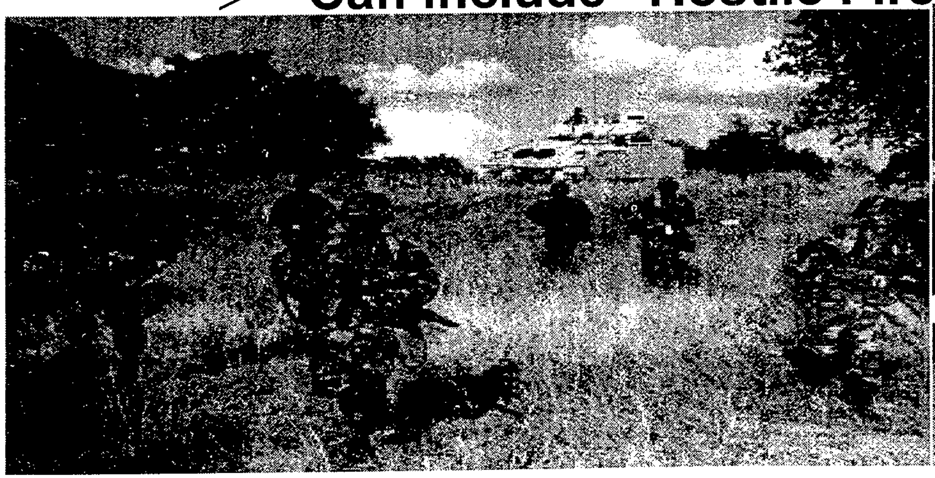
"Close with the enemy by means of fire and maneuver to defeat or capture him, or repel his assault by fire, close combat, and counterattack"

Agenda

- The Infantry Mission
- Environmental Challenges
- Operational Challenges
- Non-Lethal Tasks
- Current Solutions
- Future Focus
- Conclusions

Core Tasks

- Be weather and terrain independent -- fight or operate anywhere
- Provide global reassurance, deterrence, and when necessary, enforce compliance with US interests and objectives
- Respond to any contingency mission:
  - - War / Combat
  - - *Stability Operations
  - - *Support Operations
    - >* Can include "Hostile Fire"



Environmental Challenges

- Unrealistic to “assume away” civilians and non-combatants on today’s battlefield - Often a key obstacle to mission success!

- Soldiers must be abie to execute their missions in spite of, and/or operating in the midst of, civilian personnel

- Only acceptable option for U.S. Forces to deal with civilians is by ROE and non-lethal measures

Operational Challenges

- Meeting the demands across the conflict spectrum
  - Quickly transition from stability / support operations (peacekeeping / humanitarian assistance) to combat operations and back -- as required
  - Minimize loss of life -- US/others -- and collateral damage

Future

- More Stability Operations and Support Operations
- Increased urbanization
- Increased interaction with noncombatants

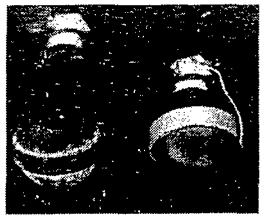
"Future is Now"

Current Non-lethal Tasks

•Six common tasks from CINC and Service Mission Need Statements serve as basic building block.

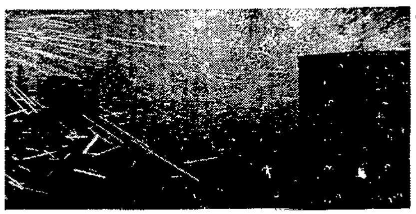
KINETICS

RCAs

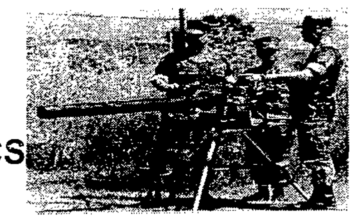


ENTANGLEMENTS

PYROTECHNICS & STUN



ACOUSTICS



1. Stop a Vehicle
2. Stop an Individual
3. Incapacitate Individual
4. Block/ Deny An Area
5. Neutralize Equipment
6. Neutralize A Crowd

Need solutions now, providing warfighter units means of operating in all environments with Non-lethal as well as lethal options.

Current Non-lethal Capabilities

- Today-- Have some solutions, however. . .
  - -- Limited to conditional use of Kinetic Munitions and RCAs (ie:CS and Pepper Spray)

Problem: Lack of materiel solutions and "consensus of use" limit Soldiers to using "basic tools" (threats, clubs, or lethal weapons)

Current Requirements

Capability Sets:

- take Non-lethal from an individual response (riot batons and pepper spray)

- to a deployable "kit of capabilities" to allow unit / commanders to respond at tactical distances

Point: Must be down to unit / commander / leader / Soldier level to employ in accordance with ROE

ARMY/USMC MOUT ACTD
(Test Bed for Solutions)

NL MOUT REQUIREMENTS

- Personnel/Crowd Control
  - Incapacitate/Stop individuals
  - Distract/Stun Individuals
  - Seize Individuals
  - Control Crowds
- Vehicle NL Systems
  - Stop a Vehicle
  - Disarm/Neutralize Equipment & Vehicles
- Area/Building NL Systems
  - Deny an Area/Facility (Vehicles & Personnel)
  - Clear a Facility (Non-Combatants)
- Force Protection/Security

CRITERIA:

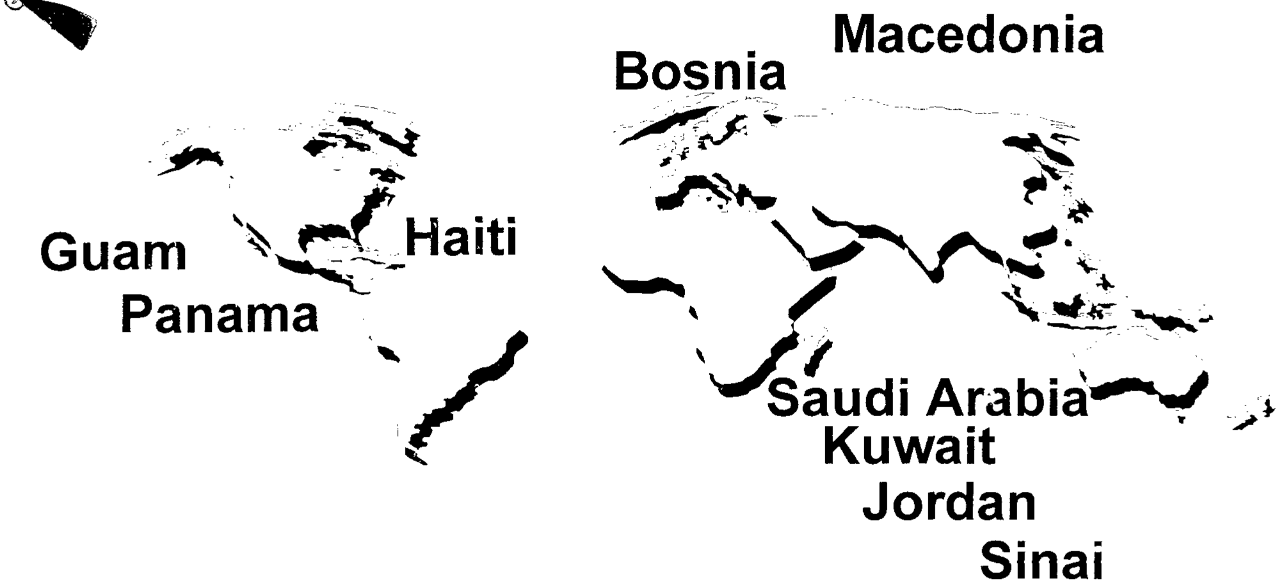
- Adapt to Existing & Developmental Platforms
- Standoff Range
- Light Weight / Man Portable
- Inflict Little or No Collateral Damage
- No Permanent Injury to Individuals (Civilian or Friendly)
- Easy to Train/Use/Employ
- Low Cost
- Safe for User
- Soldiers Maintain Lethal Capability

Future Focus

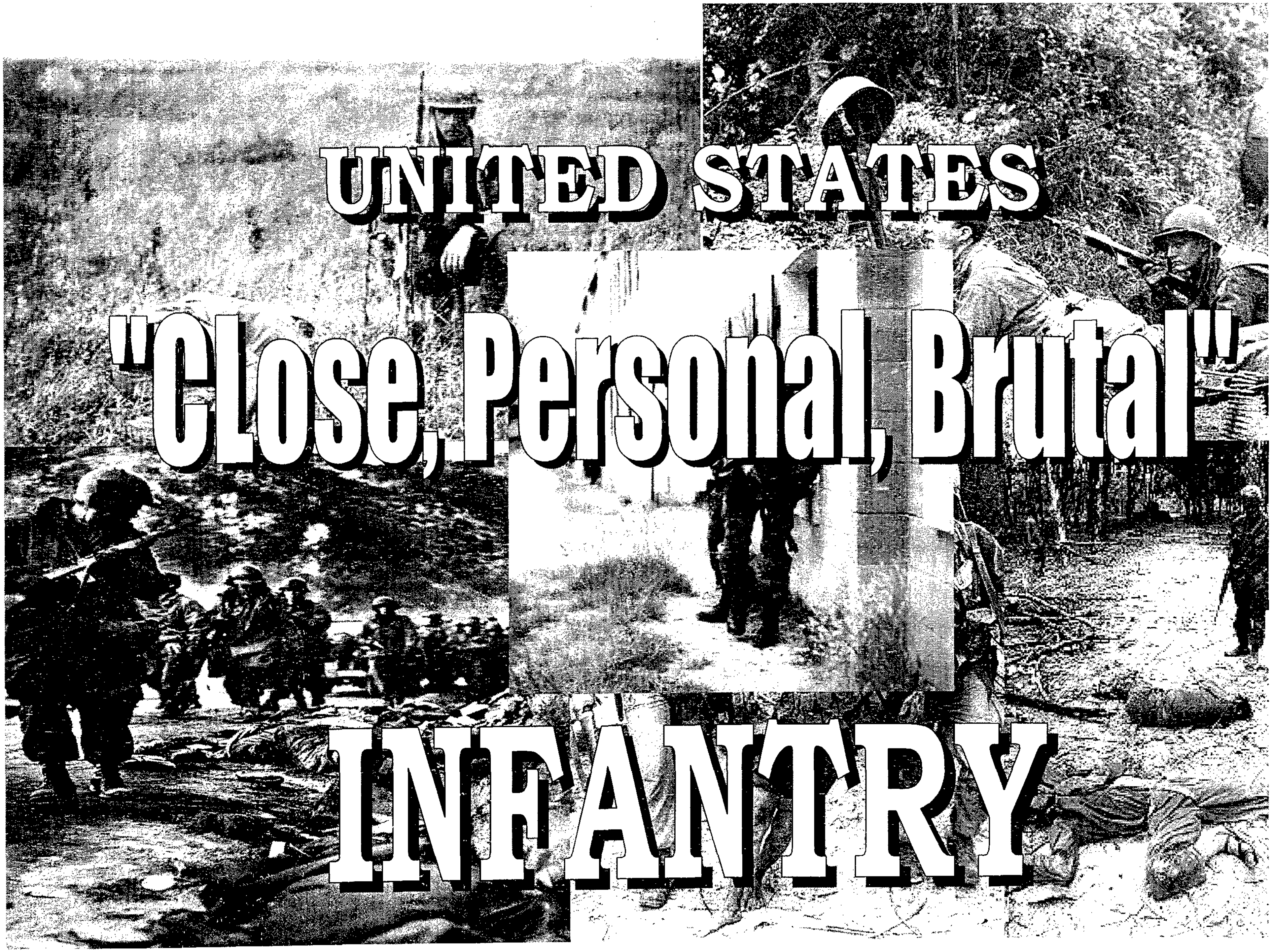
Integrate non-lethal and lethal systems to increase efficiency overall -- LW / OICW

RULE: No reduction in lethality/mobility

Conclusions



- Present Joint Non-lethal Program a good start -- long way to go!
- Army (& USMC) fully committed to effort -- must provide Soldiers on the ground the right tools to meet mission requirements
- Must focus on the Present and integrate into future systems


UNITED STATES
"CLose, Personal, Brutal"
INFANTRY

Plasma Beam EM Device
10/6/97 4:03 PM
A means of efficiently direction a high frequency electromagnetic discharge in the the form a a directional beam has been demonstrated. This device is capable of projecting tens of kilowatts of average power. Peak power levels may be much higher, as much as tens of megawatts.
This device can be used for directing RF discharges onto the conducting bodies of automobiles. This device can be used for the direct injection of RF currents, or pulsed high peak currents into the cars ignition systems and electronics.
At present SARA is pursuing an engineering effort to modularize and productize this technology for the stopping of fleeing vehicles in high speed pursuits.
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